DISCOVERY

THE PROGRESS OF SCIENCE

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H. D. Turner
B.Sc., Ph.D.

THE 'MYSTICISM' OF PROF. BERNAL
Prof. Herbert Dingle

AIRCRAFT NOISE AND ITS REDUCTION
N. Pilpel, *B.Sc., Ph.D.*

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Prof. Donald R. Griffin

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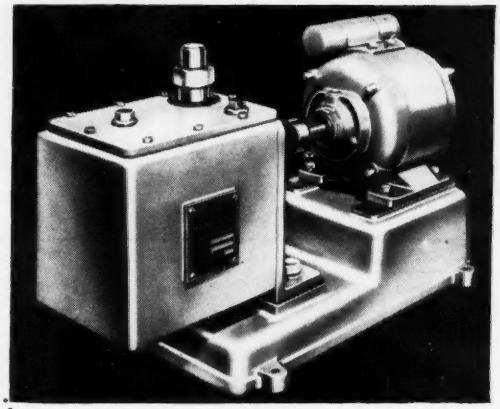

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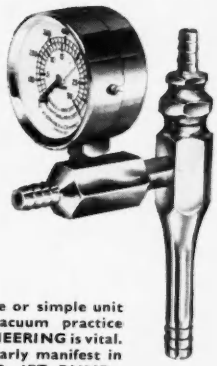

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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

Editor WILLIAM E. DICK, *B.Sc, F.L.S.* *Editorial Office* 244 High Holborn, WC1 Chancery 6518
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THE PROGRESS OF SCIENCE

COLONIAL RESEARCH

The research activities in the British colonies have been increasing steadily in the past few years, and financial support for them has been forthcoming on a considerable scale. Since 1940 approximately £13 million has been allocated to research and development schemes which have been organised, the money being provided under the Colonial Development and Welfare Acts. Of that £13 million, approximately £8 million has been disbursed, according to the latest report of the Colonial Research Council, which is printed as the first part of the publication entitled *Colonial Research 1953–54* (H.M. Stationery Office, 7*s.* 6*d.*). The actual expenditure for the year covered by the report was just over £1¼ million. Many schemes receive additional financial support from individual colonial governments.

It is interesting to see how the money is allocated to the particular broad categories into which the various research and development schemes fall. Because agriculture is obviously of major importance in the colonial empire, it is no surprise to find that 33% of the £13 million was allotted to agricultural, animal health and forestry schemes. The figures given in the report for the other categories are as follows: 15% for medical research, 12% for fisheries research, 10% for tsetse and trypanosomiasis research, 9% for social science and economic research, 8% for insecticides research, 5% for research sponsored by the Colonial Products Research Council, 3·3% for anti-locust research and 4·6% for miscellaneous schemes including building and road research.

A big variety of colonial research problems are now under investigation, and the organisation of all the various researches is now a quite elaborate affair. Planning and supervision at the top level now depends on three research councils—the Colonial Research Council, the Colonial Products Council and the Colonial Social Science Research Council. Then there are five committees which consider in more detail specific research projects coming within the various broad categories mentioned above; there is, for instance, a Colonial Insecticides Committee and a Fisheries Advisory Committee. The work on locusts is the concern of the now famous Anti-Locust Research Centre which is housed in the Natural History Museum, London, and directed by Dr. B. P. Uvarov.

Colonial Research 1953–54 contains reports by all these research councils and committees, and at the end of each there is a list of research papers by the scientists who do the actual field and laboratory work. One gains the impression that today the limiting factor so far as the solution of the colonial empire's scientific problems are concerned is the availability of scientific manpower rather than money. In one case the document does mention a specific manpower shortage; it says that the lack of qualified meteorologists continues to restrict research work. But this situation applies in many other fields of research. The Colonial Research Service can absorb a good many more scientists, and anyone interested in the career prospects it offers should write for particulars to the Director of Recruitment, Colonial Office, Sanctuary Buildings, Great Smith Street, London, S.W.1.

SCIENCE IN THE COAL INDUSTRY

Coal is Britain's most precious raw material, but the winning of this vital mineral and its utilisation have not benefited to the full from an intensive application of scientific research, though the work done on certain limited problems has demonstrated the value of this approach. This fact faced the National Coal Board when it was established in 1947, and since then great efforts have been made to expand research and development activities. A most interesting account of what is now being done was given by the N.C.B.'s Director-General of Research, Dr. W. Idris Jones, in his Cadman Lecture to the Royal Society of Arts.

He began by outlining the organisation of the Board's

scientific services, which have been represented on the board by Sir Charles Ellis, F.R.S., as scientific member. (In the reorganisation announced on February 16, Mr. A. H. A. Wynn succeeds Sir Charles.) The scientific services of the N.C.B. fall into two broad categories—Scientific Control and Research. How these various services fall into these two administrative categories is shown in the following scheme:

SCIENTIFIC CONTROL, etc.	RESEARCH
Administration Intelligence Liaison	*Central Research Establishment 1 (Stoke Orchard)*
Scientific Control	*Central Research Establishment 2 (Isleworth)*
Coal Survey	
Field Investigation	*Extramural Research*
Pneumoconiosis Field Section	*Medical and Human Problems*

Dr. J. Bronowski is in charge of the Stoke Orchard research unit, and Dr. Tyte directs the researches at Isleworth. Extramural Research comes under Mr. A. Whitaker, and the programme for which he is responsible involves a great many projects; there are, for instance, about forty projects being carried out in twelve universities. In addition, the N.C.B. subscribes liberally to various Research Associations; an example is the Hydromechanics Research Association at Harlow which is studying the problems of coal pumping for the Coal Board. Expenditure on research works out at the equivalent of one penny on every ton of coal mined, and the research side employs a staff of about 700 persons. (The corresponding figures for the scientific control side are 1*s.* 4*d.* per ton of coal, and about 2500 persons.)

Dr. Idris Jones, Coal Board's Director-General of Research.

Dr. Jones had a good deal to say about the problems connected with coal cutting that are being investigated by scientists and engineers. He mentioned some of the most efficient coal-cutting machines that are available—the modern Jib, Meco Moore, Samson Stripper and Coal Plough. But it needs to be appreciated that effective mechanisation of a mine cannot be achieved by simply ordering a machine from a manufacturer and installing it underground. The choice of machine must take into account the particular requirements at the particular mine; for example the type of coal to be cut is one decisive factor that must be considered. This can be illustrated by the case of the Coal Plough which comprises in essence a blade which is drawn along the coal face, planing the coal from the seam and loading it on the conveyor running parallel to the face. The coal ploughs developed by the Germans showed great promise when operating on the relatively soft coals of the Ruhr, but were not immediately suitable for general use in British mines. Their successful application to the harder British coal involves either making a more efficient blade or devising means of generating the higher force demanded by a conventional blade.

The efficiency of a coal cutter depends on a number of variables—the hardness of the coal itself being the most obvious one—and the study of these factors underground by N.C.B. engineer scientists since the war is a good example of what is known as "operational research". Once again Dr. Jones cited the work that is being done on the coal plough. One of the aims is to generate greater force to propel the blade. The forces already employed had been increased up to the limit set by the size and strength of the haulage equipment. The depth of cut taken by the plough had also been reduced to the minimum consistent with the production of a reasonable size of lump coal, output being maintained by a proportionate increase in speed along the face. The problem remaining to be solved was to generate greater force without increasing the tension in the haulage rope, that is, by the employment of inertia by accelerating a mass with the force available and making the coal bring it to rest in a shorter distance, thus generating greater force than the accelerating force, i.e. the plough was made percussive. Laboratory tests had already shown that the force propelling a blade fluctuates widely from the high values necessary to create fracture to the low values involved in clearing away the broken coal. It was accordingly proposed to use the haulage force to initiate percussion only when the force tended to exceed a predetermined limit. This rendering of a machine sensitive to its environment by means of a simple servomechanism has given very promising results. An experimental plough, powered by compressed air has cut at a high rate a very tough seam in South Wales. In fact it was sufficiently promising to encourage the direct development of a prototype production machine which, if all goes well, will be producing coal this year.

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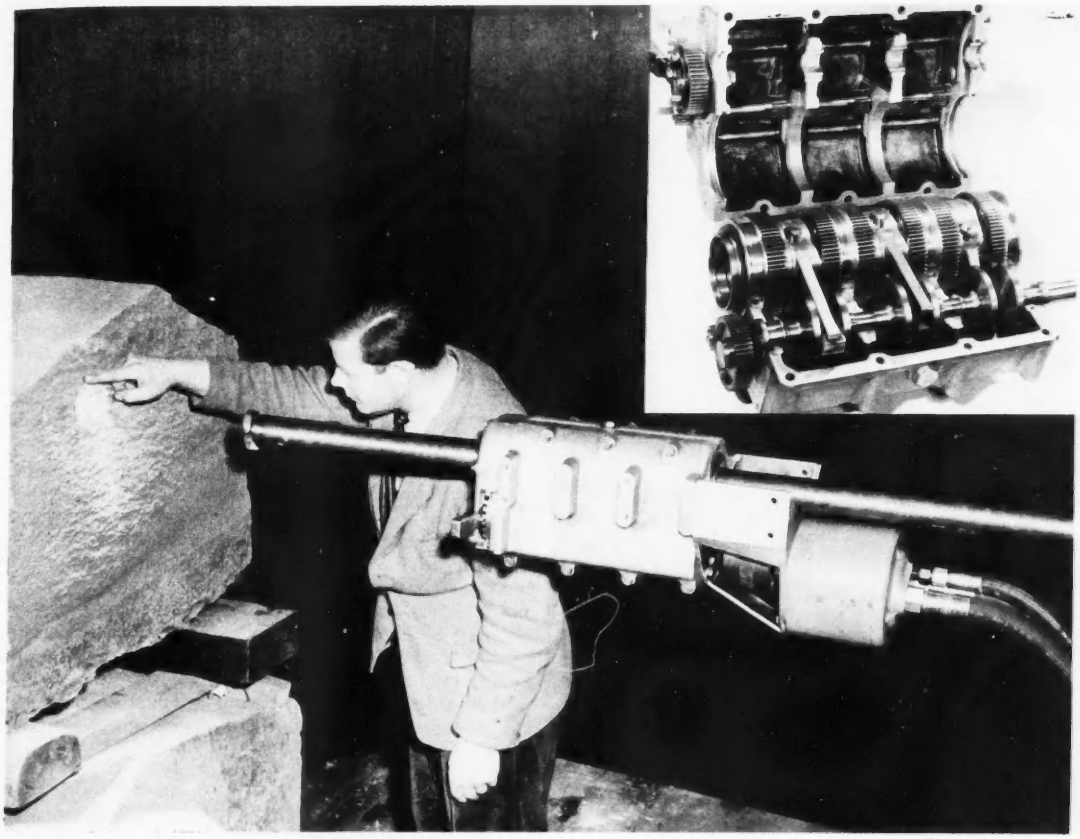


FIG. 1 (*above*). The new drill which the Coal Board is developing. (*Inset.*) The reciprocating rachet mechanism, which performs a dual function: it rotates the drill, and also allows for the drill to be passed though it on the forward thrust.

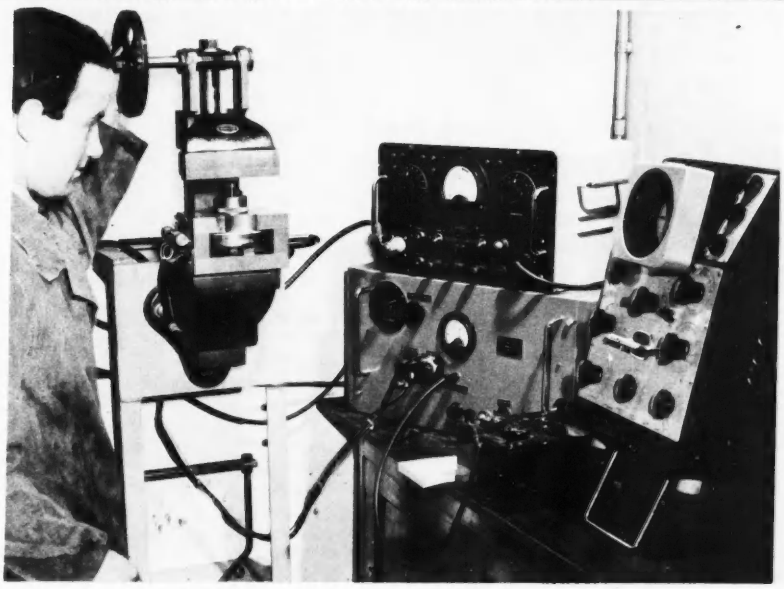
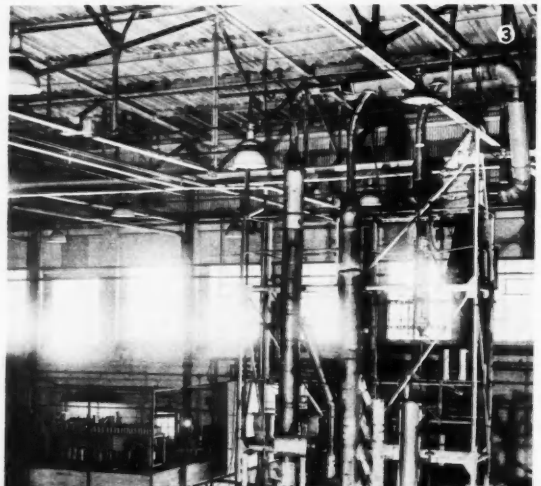


FIG. 2. Basic facts about coal breakage are being collected in the Coal Board laboratories at Isleworth. Here the coal sample under test is held in a small cylinder seated in the vice; the leads shown in the photograph connect with the electronic strain gauge equipment.



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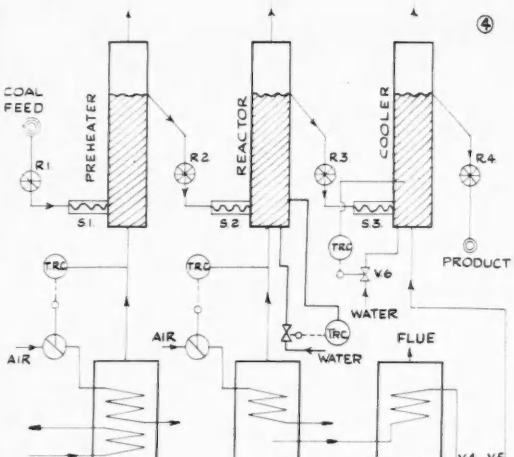
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REACTOR
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S1
S2
S3
PRODUCT
TRC
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AIR
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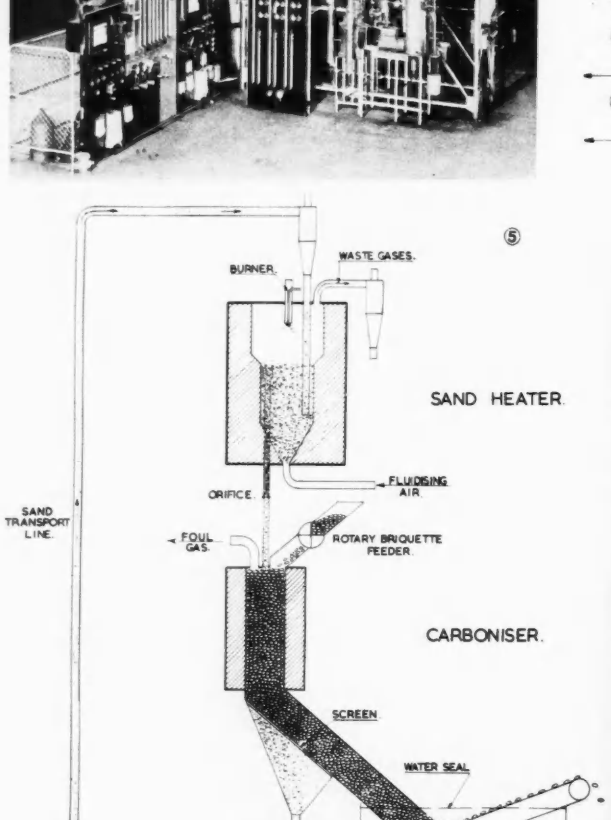
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BURNER
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ORIFICE
SAND TRANSPORT LINE
FOUL GAS
ROTARY BRIQUETTE FEEDER
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SAND VALVE
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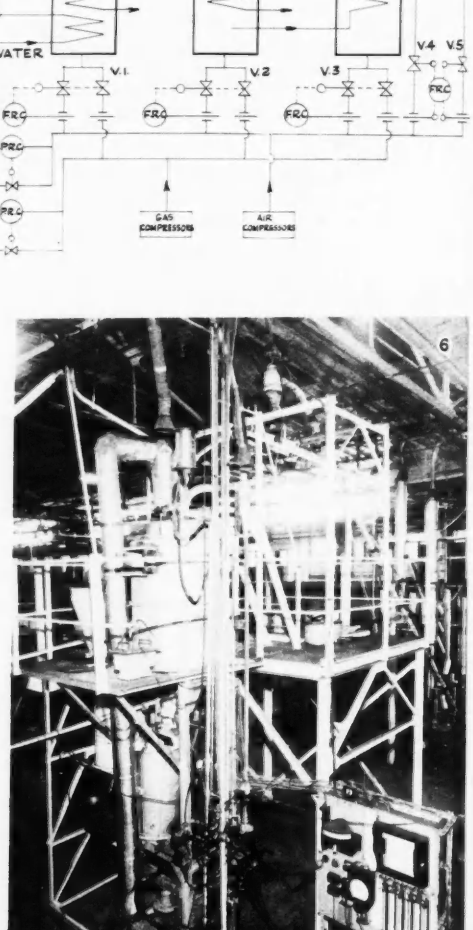
GAS PIG



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This is an example of applied research carried out in order to adapt a particular piece of machinery to meet a new set of operating conditions. Knowledge of how coal breaks under stress is of fundamental importance in connexion with coal cutting, and the facts about that phenomenon, which are matters of basic research, are being collected by scientists at Isleworth. This work involves measurements of tensile strength and compressive strength—the latter can be obtained by studying the behaviour of cubes of coal when they are crushed. The general picture of what happens when coal is stressed to breaking-point is as follows. Before it actually breaks, coal behaves more or less as a simple elastic material, i.e. its compression or extension is directly related to load. When breakage occurs the elastic energy which is stored during the application of load is released suddenly and the coal appears almost to explode and chips fly from the cutting edge with great speed. Anthracites are exceptionally strong and brittle and break conchoidally into sharp-edged prismatic fragments. As the rank decreases the strength falls to a minimum, and then increases until the low rank coals are tough and strong, with compressive strengths near those of anthracites, although they do not break in the same way as anthracite and their fragments are not very sharp. A low rank coal such as Barnsley Hards shows the "creep" phenomenon when stressed short of the breaking-point over long periods. Anthracite does not show "creep", and this may explain the "coal bursts" which are observed in anthracite mines. Interesting applications of basic research have been made at Isleworth in laboratory studies of coal cutting, e.g. the energy required to break the same quantity of coal by dynamic impulses from a similarly shaped cutting tool. For small impulses there was a large waste of energy and the blow merely produced an elastic strain with no fracture of the coal. As the blows became harder breakdown occurred with increasing efficiency up to an optimum value. Above this value energy was again wasted and the fragments were broken from the lump with high speed, without affecting the ultimate size distribution of the broken coal. These results are being applied to the design of production methods involving the ploughing of the coal seam.

Another matter which is being thoroughly investigated is the process of drilling. Drilling holes in hard rock is a quite different proposition from drilling holes in coal, and in the past the rotary drill had been used only for the latter. A rotary drill with a percussive action could provide a tool suitable for both purposes, and the N.C.B. is well on the way to perfecting a machine of this type. It would clearly be a great gain to have a tool that could do the jobs that previously required two tools.

Dr. Jones referred to the potentialities of coal pumping, which we have already discussed in DISCOVERY (*see* Aug. 1952, pp. 235–6; Feb. 1953, pp. 38–9; June 1954, p. 222). The essence of the method depends on the fact that a suspension of coal particles in water can be pumped as a fluid. The Coal Board is interested because they visualise this method could be developed to the point when it provides a good method of shifting the mineral from the coal face to the surface. A most important advantage which would accrue from the use of hydraulic transport underground would be the great reduction of fire and explosion risks, and of the dust raised by conventional methods of coal transport, and financial savings in respect of precautionary measures necessary to counter these hazards. Coal pumping would also be most useful to convey the coal from a number of pits to a central washery and from washeries to power stations and other points of use, thus avoiding multiple handling of the coal into and out of rail wagons, etc., and overcoming obstacles such as railway lines, buildings and rivers.

Coal is not only our primary source of heat and power but also an essential factor in the production of metallurgical coke, chemicals, plastics, textiles, etc. There is abundant scope for further research on this side which engages the attention of a number of N.C.B. scientists. For example, at both Isleworth and Stoke Orchard investigations are being carried out on various problems of coke preparation. These are being treated as urgent problems because the demand for hard coke and solid smokeless fuel is steadily increasing (the promised implementation of the Beaver Committee Report on atmospheric pollution will step up the rate of increase still further) whereas the best coking coals are becoming scarce and expensive to mine. One objective of the research effort at Stoke Orchard is to perfect methods for making good and better quality hard cokes by scientific blending of the weakly caking coals with the best coking coals and by improved processing of the second grade coking coals. This particular project has

This pilot plant at Stoke Orchard, which converts coal into a new type of fuel, exploits fluidisation to the maximum. The first step in the process (not shown in these pictures) is the grinding of the coal to powder. The succeeding steps are oxidation, briquetting (also not shown) and a special type of carbonisation (called "sand carbonisation") for the briquettes.

FIGS. 3–4. The coal powder undergoes slight oxidation in this plant. The flowsheet (Fig. 4) shows how the materials circulate in this fluidised oxidation. The cross-hatching represents the fluidised beds in the three vertical towers.

R1–4	Rotary valves	V1–5	Control valves
S1–3	Screw feeders	FRC	Flow-ratio controllers for fuel and air
TRC	Temperature controllers	PRC	Pressure controllers

Visible in the photograph alongside are the fluidised preheater, reactor and cooler of Fig. 4. The coal powder is given a preliminary heating in the preheater; the combustion of a mixture of air and coal gas provides generated heat inside both the preheater and the reactor.

FIGS. 5–6. Diagram and photograph of the sand carbonisation unit. In the bottom chamber briquettes are fed in through a rotary valve and pass down with a falling stream of hot sand. A screen separates the briquettes which are cooled in a water seal and conveyed away. The sand circulates in a continuous cycle; it is pneumatically lifted to the top chamber where accumulated impurities are burnt off in another fluidised bed.

made good progress, and full-scale trials are now being made of one promising process in order to find out the best blends and the best temperatures to use when the process is used on the industrial scale.

Phurnacite will be well known to many of our readers who have closed heating appliances in their homes. At Stoke Orchard a new type of fuel suitable for such appliances is in process of development; there is, in fact, a pilot plant which handles a ton of coal an hour. In this new process the powdered coal is given a preliminary heating, which brings about a mild oxidation; the resultant material is then made into briquettes, using pitch to bind the slightly oxidised particles together, and the briquettes are then carbonised. Readers interested in technical details of this process should study the pictures on p. 92. Another new Coal Board process which looks as though it should meet the needs of those who need a smokeless fuel that burns well in open grates. Both these processes, we would stress, are still at the experimental stage, and these two new fuels are not likely to be put on the market for some time.

These are only some of the interesting lines of research and development that the N.C.B. scientists and engineers are working on, and the reader who wants to read the full lecture should look up the *Journal of Royal Society of Arts* for March 4.

ATOMIC POWER AT DOUNREAY

After a visit to the site of the atomic power station that is to be built in Scotland, we can give some more details about the Dounreay project which was mentioned in the last issue of DISCOVERY.

With the development of the Dounreay atomic site in Caithness, Britain's programme for the exploitation of nuclear energy as a source of industrial power enters its second phase. For here, on the bleak and sparsely populated slopes to the westward of Thurso where Scotland reaches down to the sea, the United Kingdom Atomic Energy Authority are about to start building a power station which, apart from generating electricity, will create more atomic "fuel" than it consumes. Sir Christopher Hinton, F.R.S., who directs the Industrial Group of the Atomic Energy Authority, has described Dounreay as the future proving ground for atomic power station developments. Several types of nuclear reactor would be tested there in the course of time, he has said, "because the best type is still anybody's guess".

Dounreay's first reactor will also be the world's first full-size breeder-type power reactor. Small pilot models of low energy are already running in this country and the United States; but nothing on the scale planned for Dounreay has yet been attempted. It is expected to be operating in four years' time and will be used primarily for the solution of the many problems which still surround the development of fast "breeder" reactors. Electricity will also be produced indirectly by using the heat within the reactor to create steam to drive conventional generating equipment, and the power will be fed into the national electricity grid system.

A small core of highly enriched uranium will form the "fuel", and the heat generated within it will be carried away to a heat exchanger by means of a closed-cycle system using liquid sodium, or a liquid sodium/potassium alloy. Surrounding the core the breeder material will be placed; uranium 238 is likely to be the first cladding used, and the fission process would translate part of this into plutonium, a secondary nuclear "fuel". Thorium is also likely to be used as a cladding material in a later experiment. The reaction will be controlled in the normal way, the control rods descending by their own weight into the core. Being a fast reactor, no moderator will be used to slow down the neutrons before they cause fission, so that the core and the fuel elements will be small. The whole unit will be encased in a concrete "biological shield" and finally contained in the bottom half of a vast steel pressure sphere 150 feet in diameter. This will be supported well above ground-level in a great concrete "egg cup", which will also directly carry the weight of the nuclear reactor on a structure extending through the shell. The upper half of the sphere will be working space, where facilities will be provided for "fuel" replenishment and other maintenance needs.

The first contract to be announced by the Atomic Energy Authority in connexion with the Dounreay Project was awarded to the Motherwell Bridge and Engineering Company for the sphere. Nothing quite like it has been built before, and the structural problems are considerable. Shaped plates of various thicknesses, depending upon their positions in the sphere, will be shipped to the site; there they will be welded together into sections large enough to be raised into position by a specially designed crane, which will run on a circular track and so be able to form the sphere from the outside. Every seam will be radiographed to guard against leaks, which could be serious since the sphere will contain gas under high pressure and this gas would be contaminated with any fission products that would be released if the reactor were to "run away". In such a circumstance the uranium might melt with an uncontrolled rise in temperature and radioactive fission products would be released; the sodium coolant could also run free, with all the danger of fire. The sphere is thus the "last ditch" defence against a break-out which might endanger public health in the vicinity.

But Dounreay is so remote from civilisation. The site for the atomic station was once a naval air station, though this was never in fact used operationally. Excellent maintenance has been carried out by the Admiralty over the years, and when the Atomic Energy Authority took over recently they found most of the hutments ready for occupation. Now a security fence is being erected around the old airfield; additional accommodation is being built at Thurso, a few miles away, for the constructional teams who will soon be working on the site—when the job is in full swing they will number 1500 to 2000. On completion the station will employ about 600, most of whom will be skilled technicians and scientists; at first it is expected that at least half the number will have to be imported into the district.

The project is welcomed in the Far North—a refreshing reaction when one recalls local objections that have

been raised to certain other atomic developments elsewhere. It is seen to offer an inducement to labour to stay in the area, rather than looking much farther south for work, which has become almost a habit with the younger people. Bearing in mind the need for a steady supply of skilled workers, the local education committee have decided to rearrange their plans so that children can be given greater opportunity to receive specialised training to fit them later for positions at the atomic station. A new secondary school is to be built which will provide a higher degree of scientific instruction, and advanced evening classes are planned. The Atomic Energy Authority have promised their full support for all schemes calculated to produce "locally-grown" scientists. (This policy is already proving its worth in Cumberland; the establishment at Sellafield, for example, has most successfully integrated its interests with those of the local communities.)

Dounreay's future is not only important to Thurso or Caithness; but to Great Britain as a whole. And the great steel sphere, dominating the rest of the atomic station and poised above the rocky and most northerly mainland shore, is perhaps symbolic of things to come.

A RUNAWAY NUCLEAR REACTOR

Most people have regarded the possibility of a nuclear reactor getting out of control as a dreadful prospect. But it is a possibility with which the technical experts have to reckon, and one of them, Sir Christopher Hinton, suggested in 1954 that the best way to settle the question would be to let a reactor run away with itself, the experiment to be carried out in a remote spot to minimise risks.

Now, according to the Scientific Correspondent of *The Financial Times* (31.1.55), this type of experiment has been carried out. A nuclear reactor was deliberately allowed to get out of control recently at the United States Atomic Energy Commission's Reactor Research and Development Station in Idaho.

All the safety control rods which maintain the "burning" of the atomic fuel were withdrawn so that the reactor could burn itself out.

The results proved far less disastrous than might have been expected, since after an initial period of "running away" in which rapidly increased fission and the generation of excessive quantities of heat occurred, the reaction slowed down and then stopped. The reactor had in fact proved self-controlling, the rapid increase in fission having created conditions under which the reaction necessary for the continued "burning" of the atomic fuel could not be maintained. The report in *The Financial Times* concluded by pointing out that a large number of the nuclear reactors so far constructed are of the self-controlling type, but other types of reactors, such as those using "fast" neutrons which are capable of "breeding" more atomic fuel than they burn up do not come in this category.

BOSCOMBE DOWN

When a new high-speed fighter is born it is not enough to say that it flies at 700 m.p.h. or more. Absolute speed, vitally important though it is in the interception of enemy aircraft, is not the only requirement. The fighter must be able to manœuvre in the air, and if it cannot use its guns effectively then all the speed at the pilot's command is useless. As we have advanced further into the "Jet Age", fighter aeroplane designers have found it increasingly difficult to match speed with manœuvrability. It is one thing to make an aeroplane fly faster than sound in shallow dives and nearly supersonically in level flight, but it is an entirely different problem to make that aeroplane what the Royal Air Force calls an effective "gun-platform".

The task of making sure that any such new aeroplane "fills the bill" as a comprehensive *weapon* for the Royal Air Force or the Fleet Air Arm falls to the Aeroplane and Armament Experimental Establishment at Boscombe Down, near Salisbury, Wiltshire. Like Farnborough (with which it has much in common), Boscombe Down is a Ministry of Supply establishment. Its commander is an R.A.F. officer, Air Commodore A. H. Wheeler, O.B.E., M.A., who is one of the most experienced test pilots in the world and who served as one of the three technical assessors assisting Lord Cohen in the inquiry into the "Comet" disasters.

One's first impression of the big establishment with its mixture of Service people and civilian scientists involved some difficulty in deciding where the work of Farnborough left off and that of Boscombe Down began. The explanation is that Farnborough is concerned with research and development work contributing to the design of new aeroplanes and equipment, whereas at Boscombe Down the finished product is reviewed and studied.

Boscombe Down's origins go back to the 1914–18 war, during which the Royal Flying Corps, predecessor of the R.A.F., set up a specialised test flying unit at Martlesham Heath, Suffolk, to carry out the acceptance trials of aircraft for the Service.

Today the A. & A.E.E. is one of the most important aeroplane-testing establishments in the world. Its main runway, 3400 yards long and 100 yards wide, is the largest in Britain, and the establishment's huge main hangar dominates the local skyline. This hangar is 60 feet high, 250 feet wide and 200 feet long. In its floor there is built-in precision weighing apparatus capable of recording the weight of aeroplanes up to 120 tons.

Boscombe Down has many laboratories and workshops where the establishment's staff scientists and technicians devise and develop their own flight test instruments and also apparatus that is required for calibrating and testing radio, radar and other intricate equipment used in modern flying. Their tests do not end with aeroplanes. For instance, the new clothing that has had to be designed for jet pilots flying at great heights is thoroughly tested and proved by Boscombe Down pilots before being issued generally to the Royal Air Force and the Fleet Air Arm.

There are four squadrons at Boscombe Down. "A" squadron deals with fighter and trainer aeroplanes; "B"

squadron with bombers and transports; "C" squadron is concerned with Fleet Air Arm aeroplanes, while "D" squadron looks after helicopters and parachute testing. All the new aeroplanes go to the appropriate squadron for months of the most thorough test flying. The test pilots are R.A.F. and Fleet Air Arm officers, most of whom have taken the course at the Empire Test Pilots' School at Farnborough. The first thing they do when they receive a new fighter or bomber, or any other kind of aeroplane for that matter, is to check its handling qualities; to assess how well or otherwise it can be flown by the average Service pilot. The object of these initial tests is to make sure that the aeroplane has no "vices" which might cause a high accident rate among pilots. Then along with the flying characteristics, the test pilots have to satisfy themselves that all the many radar installations on modern war-planes work as they should.

So far as armament is concerned, the establishment has extensive gunnery and bombing ranges on Salisbury Plain. There, with last war aeroplanes as targets, Hunter and Swift fighters of today can be seen demonstrating the devastating fire-power of their 30-mm. Aden guns, and other aircraft carrying out attacks with air-to-ground rockets.

Boscombe Down also maintains a tropical experimental unit in North Africa, and is responsible for tests of certain equipment under Arctic conditions in Canada. In addition, there is also a small civilian test pilots' section.

Air Commodore Wheeler, who is fifty-one, was formerly in charge of experimental flying at Farnborough. During the war he himself tested many German aircraft which came into our hands, enabling our pilots to get detailed knowledge of the enemy's performance in the air. Immediately under him is the Chief Superintendent, forty-two-year-old Mr. Handel Davies, M.Sc. Mr. Davies joined the staff of the Royal Aircraft Establishment, Farnborough, in 1936, and was engaged on wind-tunnel research until 1942, when he went to the Ministry of Aircraft Production. After the war he returned to Farnborough as head of the aerodynamics flight section, remaining there until he moved to Boscombe Down in 1952. (Since this note was written the Air Ministry has announced that Mr. Davies takes over the post of Scientific Adviser to the Ministry on March 1.)

SCIENCE AND ADULT EDUCATION

H. D. TURNER, B.Sc., Ph.D.

Many flourishing courses that deal with various aspects of science and technology are organised by the Extramural Boards of our universities. The views expressed in this article are based on experience of such courses dating back to 1946 when Dr. Turner began lecturing for the Extramural Department of Sheffield University. Since 1953 he has been Staff Lecturer in Science in this department, and is responsible for organising all its scientific and technological courses.

It is widely accepted that modern experimental Science had its origin in the general intellectual emancipation of the 16th and 17th centuries. The subsequent expansion in the quantity of scientific research work has been accompanied by the development of a most impressive and effective Technology, and this has enabled Man to exercise increasingly effective control over his environment. The consequent material advantages have not, however, been attained without sacrifice, and many of our social and political problems, both inter- and intra-national, stem from the impact of Technology upon primitive forms of society. With most of these problems unsolved, we now face a future in which vast and far-reaching changes have been made possible by the technological developments of the last war.

During its development, Science has been subdivided into separate subjects such as Chemistry, Physics, Biology and Geology. It is unfortunate that this subdivision, although essential to scientific progress, has not been accompanied by the growth of studies capable of critically appraising the relative developments in, and correlating theories and concepts between, the various subjects. Thus there is at present no generally accepted account of the scope, methods and limitations of Science and Technology; and this is particularly to be deplored, since it is this sort of information which the average man should possess when making decisions on the personal and social problems with which he is from time to time confronted.

The Science teaching with which the writer has been connected has been designed to provide information on, and discussion of, all these topics for people of various types and abilities.

The major difficulty is found in attempting to present scientific information in attractive and palatable form, capable of arousing and maintaining the interest of students, whilst the subject is being developed in its early stages. There is little doubt that the average audience, even if it could be assembled, would be repelled by any attempt to teach Science before some sort of scientific picture had been built and a rudimentary scientific vocabulary acquired. It is necessary, therefore, to find a way of attracting people and of providing them with a basic vocabulary, some familiarity with scientific concepts, and an interest in Science, before beginning discussion of the various philosophical and social problems raised by Science and Technology. Fortunately it is possible to do this, since most people are intensely

interested in Science as it affects them: in the practical applications of Science; in gadgets; and in possible future developments. Most people would rather have the effects of Science and Technology described to them than be taught Science; but this description can be arranged so as to lay the foundations of an interest in, and a capacity for the understanding of, Science itself. Once this has been achieved it is possible to begin discussion of the scope, effect and limitations of the methods of scientific inquiry; the effectiveness of this latter type of teaching is enormously increased by an historical treatment of the subject. Not only are the vocabulary and concepts much simpler when one considers, for instance, the Science of the 17th century, but the student is easily led to more complex modern theories by discussion of the relatively inadequate but readily understood theories which preceded them.

Typical of courses designed for people who, although reasonably well informed, have no immediate interest in, or knowledge of, Science was a series of six lectures entitled "Electrons in Action". In this course, which had an average attendance of ninety people, various spectacular electronic devices were described in such a way as to capture the attention of the audience, and the lectures were illustrated by practical demonstrations, slides, film-strips and films. The first lecture, after outlining some of the applications of electrons, described their discovery, properties and production. The second lecture dealt with the thermionic effect and the uses of the triode valve as an amplifier and, because of the high velocities of electrons, a generator of high-frequency electrical oscillations. This led to discussion of radio transmission and reception and, during this lecture, it was emphasised that modulation may be performed manually (as with a morse key), or automatically by a transposer (e.g. the microphone which continuously recodes the pressure variations in sound-waves into variations in electrical potential). This laid the basis for later discussion of information theory. The next lecture, on television, dealt with the way in which high-frequency electrical oscillations can be modulated so as to carry information about variations in visual patterns instead of in sequences of sounds. The process of scanning was discussed as a method of converting two-dimensional patterns of variation into time sequences, and this was used to introduce later discussion of methods of storing numbers in computing machines and of theories of visual perception. The photo-electric effect and the development of television cameras were described; and the cathode-ray tube was discussed as a presentation device in which the position and intensity of a beam of electrons can be varied independently. The fourth lecture, on radar, was introduced by consideration of the cathode-ray tube as a time-measuring device, and included discussion of velocity modulated valves and magnetrons. The next lecture was concerned with electronics in industry. After the electron microscope and x-ray tube and their use in industrial inspection had been described, inspection systems in general were discussed and it was shown how it is possible to convert any physical parameter of a system into a proportionately varying electrical signal which, after amplification, can be used to operate alarms or servomechanisms. Thus the general discussion of control systems, which formed the subject of the last lecture and which included descriptions of various new electronic machines such as computing machines, electronic "tortoises" and machines which might augment existing or replace damaged human senses, was introduced; and the series ended with discussion of the possibility of the automatic factory. The whole course was intended to describe the ramifications, and to relate apparently divergent applications, of one extremely important scientific discovery, using these applications as a means of arousing and sustaining interest. At the same time, the treatment was arranged so that some instruction in formal physics was given without the members of the audience necessarily being aware that this was being done. For instance, description of gas-filled valves involves discussion of electrical conductivity of gases, and consideration of x-ray tubes and the electron microscope is impossible without some understanding of Atomic Theory and Wave Mechanics. Frequent references were made to the relation between developments in electronics and those in other fields, and to the problems raised by the impact of Science on society.

DEMONSTRATIONS AND FILMS

A series of three lectures, presented to members of a community association, is an example of a course designed to foster an interest in Science in people whose general intellectual level was lower than that of the audience attracted to the series just described. In this more elementary series, rather more emphasis was placed on the social effects of various technical developments than on the scientific principles involved, although some functional explanation was given. The general discussion was at a very popular level, and many practical demonstrations and films were used. The first lecture dealt with the production and use of power and the demands made for it in modern industrial society. Such topics as the use of coal for power and as a raw material in chemical industry, the limited amount of coal and oil in the world, and the possibility of using alcohol as a liquid fuel and the effect of this on food production, were discussed. Faraday's work on electromagnetic induction and its consequences were described, showing how in modern society power is used in the easily deployed form of electricity. The second lecture, introduced by a brief sketch of the development of Technology from Stone Age to modern times, dealt with materials used for fabrication. Developments in the dyestuffs and plastics industries were described and illustrated by films, by the manufacture of urea-formaldehyde polymer, and by the display of samples of plastic articles. The main theme emphasised in this lecture was that Man is emerging from the time during which Technology is determined by the properties of naturally occurring raw materials, and entering a period

when technical problems may be solved by the production of synthetic materials having the appropriate physical and chemical properties. An obvious elementary example of this is the development of oil-resistant synthetic rubber linings for bullet-proof petrol tanks and for hoses used in refuelling ships at sea. The final lecture dealt with developments in transport and communication and their influence on the structure of society; this lecture, in fact, was mainly a simpler presentation of the last lecture of the series described above. The course had an average attendance of more than forty people.

Longer series of lectures have also been devised for people who have attended Adult Education classes in various subjects other than Science. Typical of these was a three-year course designed to follow a series of W.E.A. classes in economics. Since more time was available than in the shorter series, a more leisurely approach was possible, and hence a much more thorough treatment of the subject could be given. For instance, a general discussion of the ways in which modern civilisation is shaped by the enormous quantities of available power introduced discussion of the evolution of prime movers. The development of steam engines was traced from Newcomen's pumping engine to the steam turbine, and it was shown how all these devices, and petrol, oil, jet and rocket engines but not atmospheric engines, are designed to make use of the high molecular velocities produced by heat. These lectures were illustrated by films of the old Cornish pumping engines, and modern locomotives, and petrol, oil and jet engines. It was further shown that the essential differences between all these types lie in the ways in which the high molecular velocities are produced, and in the types of surface on which these molecules impinge.

The higher the molecular velocity the greater the force exerted on the piston in each stroke, and hence the smaller the area of piston face needed for a given power output. Evolution of the multi-cylinder petrol engine from the old pumping engines, therefore, is accompanied by reduction in the size and weight of piston and cylinder, and hence by an increase in the possible number of strokes per minute. Thus the overall effect is to increase the power-weight ratio of the engine, and this together with the use of liquid fuels having high calorific value and low flash-point made possible the development of the aeroplane. This exactly parallels the development of the steam locomotives, made possible by the enormous reduction in size and weight, without loss of power, of engines using steam instead of atmospheric pressure.

It is easily seen that only if all the molecules rebound from the piston face with zero energy (and hence zero velocity) will all the energy which they contained have been converted into work. We may, therefore, define the efficiency of conversion of heat into useful work by the proportion of their total energy lost by the molecules during each engine stroke. This is readily seen to be the difference between the average energy of the molecules before and after the stroke, divided by the average energy before the stroke; and since we may define absolute temperature by average molecular energy, this function may be expressed as the difference between input and exhaust temperature divided by input temperature.

This leads to further discussion of such topics as entropy, statistical mechanics, and hence prepares the ground for the introduction of atomic theory and wave mechanics. Thus, at the end of the first year of twenty-four lectures, the students had begun to see the importance of various scientific concepts such as those of energy, and atomic and molecular structure, to acquire a scientific vocabulary, and to see something of the relationship between Science and Technology. During the second year, lectures were given on the historical development of various scientific concepts, and on the interaction between social forces and technological development at various periods. The third year was devoted to discussion of the scope, limitations and power of the methods of scientific inquiry.

HISTORY AND PHILOSOPHY OF SCIENCE

Geology, Biology and Astronomy are examples of subjects in which there is wide popular interest, and courses in these topics attract large audiences. Many of these people can subsequently be diverted to a study of the History and Philosophy of Science as was done, for instance, by a series of lectures given to people who had previously studied Biology. In this series, the known interest in Biology was used in place of an interest in Technology as a means of maintaining the interest of students; and the class was led through study of such topics as the chemical constitution of amino acids and proteins, the mechanism of muscle contraction, and comparative biochemistry, to a general discussion of the laws of matter and its association, the development of scientific concepts, and the relation between physics, chemistry, biochemistry and biology. After two years of this type of study the class members attended a series of lectures and discussions on the philosophy of Science identical with that described above.

Many courses have been designed for people with reasonable knowledge of, and interest in, Science; and these courses are often more easily arranged and presented than those described above. For instance, lecture series on "The History and Philosophy of Science", "Modern Developments in Physics", "Cybernetics" and "Aspects of Evolution", have attracted large and well-informed audiences.

Whilst it is not suggested that the only methods of teaching Science and its History and Philosophy are those outlined in this article, the results obtained so far do indicate that they are successful; that the methods are applicable to all types of people; and that people who are not immediately interested in Science can be attracted to, and interested in, lectures which will eventually lead them to a keen and critical appreciation of Science and Technology, and of their place in human affairs.

THE 'MYSTICISM' OF PROF. BERNAL

Prof. Bernal's latest book, "Science in History" (Watts, 967 pp., 2 guineas) continues the line of argument he advanced in his earlier works such as "The Social Function of Science" and "Marx and Science". In this review, which is the substance of a radio talk broadcast by the B.B.C. European Service, Prof. Dingle, Professor of the History and Philosophy of Science in London University, criticises Bernal's general thesis.

PROF. HERBERT DINGLE

In the perilous times in which we live, few things are more important for the safe guidance of mankind than a right understanding of the relations between science and society. It is a truism that the material circumstances of our lives are now shaped almost entirely by means which owe their birth to scientific knowledge, and it is no less true, and little less relevant, that the mental attitude with which we face our problems is tending more and more to conform to that by which scientific knowledge is acquired. It is therefore of the first importance that we should try to understand as clearly and precisely as possible, first, what science is in itself, and second, how, on the one hand, it affects and might affect our social life and, on the other, how that social life reacts and might react on the progress of science.

We may for present purposes think of science as the discovery, on the basis of experience alone, of the laws of nature in the broadest sense; that is to say, the gradual realisation of the necessary conditions imposed on us by the nature of the world in which we live—the unalterable rules of the game of life, so to speak. Social organisation, on the other hand, is ultimately a voluntary thing, which we are potentially able to change at will within the scope allowed by the scientific laws. The question of the relation between science and society can then be clearly visualised. Knowing what we do of the necessary conditions, how can we best use the freedom that remains to us in order to obtain the kind of society we want? And, conversely, how can society in its turn help towards the extension of our knowledge of the necessary conditions?

To answer these questions satisfactorily it is of the greatest help to see what has happened in the past. Both science and society are very old, and their interaction, though very slight in the early stages, has probably never been wholly non-existent. But until nearly our own time it has been mainly unconscious. Scientists and statesmen have worked in isolation from one another, and neither has been aware of what he owes or might owe to the other. Nevertheless, the relationship has been there and it is a vital task of the modern historian to bring it to light and trace its course through the ages. To do this properly the historian must be also a scientist or the scientist must become a historian. Human limitations being what they are, this is impossible in the fullest degree. We must be content at the best with something less than the ideally perfect. What we can expect, however, are, first, a clear perception and presentation of the problem that is being faced, and second, a disinterested approach to the facts of history that allows its message to reveal itself as little distorted as possible by the expectations or desires of the investigator.

In Prof. Bernal's latest book, *Science in History*, neither of these things can be found. The professed purpose of Bernal's book is to trace and to interpret, from the earliest times to the present day, the interrelations between science and society of which I have been speaking. It is a massive work, containing nearly half a million words and surveying—though, of course, not with uniform thoroughness—all branches of the recognised sciences, and some which can only by courtesy be so named. The amount of learning which has gone to its making is immense, and of the seriousness of purpose of the author there can be no question. One cannot but admire these aspects of the work. But of the two essential qualities—clearness of delineation of the problem and disinterestedness of treatment—there is scarcely a trace. The subject is confused, deliberately and admittedly, from the beginning, and the facts are throughout interpreted not in the natural, and in some cases one would have thought inevitable, way, but so as to substantiate a preconceived philosophy which the author has adopted on *a priori* grounds and is evidently determined to see exemplified in whatever happens. I can but give a few examples of these characteristics; no reader will have difficulty in finding others wherever in the book he cares to look.

Consider first the deliberate vagueness of the treatment. At the beginning, Bernal openly declines to say what he means by science. "My experience and knowledge", he writes, "have convinced me of the futility and emptiness of such a course. . . . To a human activity which is itself only an inseparable aspect of the unique and unrepeatable process of social evolution, the idea of definition does not strictly apply." "The word science or scientific", he goes on, "has a number of different meanings according to the context in which it is used." Now it is not difficult to see that with such freedom from definition the way is open for almost any conclusion the writer wishes to reach. I might say, for instance, that the term, Prof. Bernal, has a number of different meanings according to the context in which it is used. It may refer to a physicist, to an Irishman, to a Marxist, to a university professor, to a father, and so on. I might then argue in the following way. Prof. Bernal (as an Irishman) conforms to laws which tend to perpetuate a capitalist form of society; therefore Marxists are people who uphold capitalism.

Now this is precisely the kind of use that Bernal makes of his freedom to vary his definitions. On one page he tells us that "an easy definition of science is *what scientists do*" and on the next page we read, "the problem of how to live has always been the first preoccupation of the scientist". The conclusion inevitably follows that science is the attempt to solve the problem

of how to live, and the way is then clear for an economic interpretation of science. I pause for a moment to notice that Bernal's statement here, as in so many other places, is not in accordance with facts. Throughout the greater part of history, scientists have been able to be scientists because they have *not* been preoccupied with the problem of how to live. But, returning to the main point, the fallacy is obvious. No doubt it is impossible to give a concise definition of science that will include all the meanings that have ever been given to the word, but what we have a right to know is not what science means in that sense, but *what Bernal means by the word when he uses it in his book*. That we are not told. He tells us, indeed, that he has "aimed at including everything called science", but he has certainly not succeeded in this. There is an activity called "Christian Science", but I have not noticed any reference to it in the book. His aim, in fact, is not to include everything called science but everything that he wants to call science, and to give the word the meaning he wants on each separate occasion. That is not the way to clarify a subject.

But what, in fact, amidst all this deliberate vagueness, is the predominant impression of science that a reader, previously ignorant of the subject, would obtain from this book? It is difficult to say precisely, but the best indication can perhaps be given by comparing the numbers of references in the index to two pairs of contemporaries: Karl Marx has 39 references, Lord Kelvin 6; Lenin has 11, Max Planck 4. It is not to be supposed that Marx and Lenin are representatives only of the society side of the relation. According to Bernal's vague specification the activities of Marx and Lenin are as truly scientific as those of Kelvin and Planck. Such is the relevance of this book to the problem facing those whose idea of science is that generally held.

The same indefiniteness characterises the conclusions reached. What, in Bernal's view, have been the historical relations between the progressive development of science and the changing forms of society? It is difficult to say. It is emphasised that they are far too complicated to be expressed in terms of simple cause and effect, but the only contribution to an understanding of what they are consists of a supposed parallelism. The major developments of science and the major changes of society are said to have occurred at the same times and places and to have similar characteristics. But when we examine the evidence we find that this amounts to very little. All societies undergo changes, and science throughout its history has developed. Hence wherever and whenever we look we shall find coexisting a developing science and a changing community. The fact, if it be a fact, that the most radical changes in both phenomena occur among the same people is a natural consequence of the fact that that people forms a progressive community, and is no indication at all of any connexion between the two phenomena. One would not expect science to develop most rapidly in France and society simultaneously to refashion itself most fundamentally in Labrador, even if the two activities were totally unconnected. In order to establish a relation between the changes some community of character must be shown to exist in them, and here Bernal fails badly. Even after selecting, from his infinitely vague idea of science and his almost equally indefinite idea of what is most fundamental in social relations, the factors that appear to show most similarity, he can find nothing that will convince an unbiased reader that he has found anything of significance.

One example must suffice. Speaking of Newton's work in the 17th century, he writes: "Newton established, once and for all, the *dynamic* view of the universe instead of the *static* one that had satisfied the Ancients. This transformation, combined with his atomism, showed that Newton was in unconscious harmony with the economic and social world of his time, in which individual enterprise, where each man paid his way, was replacing the fixed hierarchical order of the late classical and feudal period where each man knew his place." Thus Bernal regards the change from static to dynamic views as a basic phenomenon, expressing itself simultaneously in science and in the economic and social world. But what Bernal does not say is that in the first half of the 20th century science has changed back again, in this very same field of mechanics in which Newton worked, from his dynamic terms of expression to the static terms of geometry. Einstein's field equations are as truly static, in contrast to Newton's dynamical equations, as was the ancient view of Aristotle, though they are, of course, very different in other respects. We ought therefore to have in these days a reversion to a fixed hierarchical order in which each man knows his place. Those are hardly the terms in which a disinterested spectator would describe the present social order.

The fact is that this supposed parallelism is a pure myth—a piece of "mysticism" in Bernal's derogatory sense of the word. Science develops according to the ability of the available scientists and the existing state of knowledge, and in the field of mechanics at least, these are as little related to the order of society as the rate of fall of a body is related to its colour. The relation between science and society must be learnt from actual evidence of the effect of one on the other. To try to find it in fanciful forced analogies is mere idle trifling.

I must turn now to the second outstanding feature of the book, namely, the distortion of the obvious meaning of facts arising from the preconceived notions which the author brings to bear on them. I have time for only one example, but this is the less to be regretted inasmuch as the passage I have just quoted illustrates this point as well as the essential vagueness of the treatment. The particular prejudice in the example I am about to give is the illusion that Francis Bacon early in the 17th century regarded the main purpose of science, as Bernal himself does, as the application of knowledge to material ends, in opposition to the main body of philosophers of his own age for whom the purpose of science was the pursuit of knowledge for its own sake. As Bernal puts it, "The truth of science, as Bacon pointed out long ago, is the success of its application to material systems." In support of this view he quotes Bacon as follows:

Prof. Bernal's brilliant researches brought him a richly-deserved F.R.S. at the early age of 36. Always interested in the relationship between science and society, he wrote before the war his magnum opus *The Social Function of Science* in which he expressed his scientific and political creed. Since the war his ideas have been more warmly acclaimed abroad than they have in Britain; thus the Russians gave him a Stalin Peace Prize, but the British Association removed him from their Council for his remarks about the militaristic direction of British science.

"Nowe among all the benefits that could be conferred upon mankind, I found none so great as the discovery of new arts, endowments, and commodities for the bettering of man's life. For I saw that among the rude people in the primitive times that authors of inventions and discoveries were consecrated and numbered among the gods . . .

"But above all, if a man could succeed, not in striking out some particular invention, however usefull, but in kindling a light in Nature—a light which should in its very rising touch and illuminate all the border-regions that confine upon the circle of our present knowledge; and so spreading further and further should presently disclose and bring into sight all that is most hidden and secret in the world—that man (I thought) would be the benefactor indeed of the human race—the propagator of man's empire over the universe, the champion of the liberty, the conqueror and subduer of necessities."

Now no impartial reader can fail to see that here, as elsewhere in his writings whenever he compares the two things, Bacon is clearly setting the light of knowledge above inventions which are applications of that knowledge to material systems, yet such is Bernal's prejudice that he can set down in support of his view a statement whose meaning is the direct denial of it. The truth of science is not the success of its application to material systems; the truth of science would remain truth if it were never applied to material systems, and most of such applications have been made in terms of theories now regarded as not true at all.

I cannot close without a reference to a very regrettable feature of the book, namely, the prevalence of abuse and imputation of unworthy motives to those who differ from the author. For instance, "The increasing insistence of some scientists on the purity and freedom of science is itself an indication of an uneasy conscience as to the social consequences of their work and as to the effects of social changes on the future of science itself." Relativity, "was eagerly seized on by the disillusioned intellectuals after the First World War to help them in refusing to face realities". "The ostensible reason for rejecting a social interpretation of philosophy and religion is not the real one. The underlying reason against admitting it is that it would open the present social system to attack."

Remarks such as these are unworthy of serious attention. As a matter of policy alone, Prof. Bernal might realise that those who do not share his views are unlikely to be impressed by his advocacy, however sincere they may be willing to believe him to be, when they find it accompanied by assertions which they know to be untrue. On higher grounds than policy, he might consider the propriety of making statements for which he cannot possibly have any evidence.

AIRCRAFT NOISE AND ITS REDUCTION

N. PILPEL, B.Sc., Ph.D.

A correspondent wrote recently to the *Manchester Guardian* inviting advice on the best way of insulating himself from noise—street noise, aircraft, trains and the rest. He received all kinds of odd advice from readers, who suggested he should seal the windows of his house, hang blankets over the doors, disconnect the telephone, retire to bed with wax in his ears and his head under the pillows, and so on and so forth. Whether he benefited at all from any of these hints is a moot point. But this correspondence did serve the useful purpose of bringing home the incontrovertible fact that today noise presents a major social problem. Of all the various sources of noise probably the most obnoxious is that of modern high-speed aircraft.

Aircraft noise is a subject of considerable concern and is being tackled at the highest level. In a speech on June 28 last year Mr. Duncan Sandys, then Minister of Supply, stated that £100,000 was being spent annually on research into methods for reducing aircraft noise. The work is being carried out by various government departments, at universities, and by a number of aircraft firms on their own initiative. It is the purpose of the present article to discuss the manner in which aircraft produce noise, and to outline some of the methods by which that noise may be reduced.

NOISE FROM PROPELLER AIRCRAFT

Propeller-driven aeroplanes produce noise in three different ways. Firstly, there is the noise from the rotating propeller itself, secondly, engine and exhaust noise, thirdly, the noise from the wakes which develop as the aircraft passes through the air. This last noise might be compared to the hissing of the sea when a high-speed launch has passed. The wake noise only becomes appreciable when aeroplanes reach a speed of about 400 m.p.h., but thereafter it increases very rapidly, and when the machine is flying near the speed of sound it may constitute 90% of the total noise.

Considerable work has been done on the noise of aircraft propellers, both on the ground and in the air. Thus at Langley Aeronautical Laboratory in the U.S.A. it was found that the noise did not spread out uniformly around an aeroplane revving up on the ground but was concentrated in a zone 30° behind the plane of the propeller (Fig. 1). As the speed of the propeller is increased the direction of maximum noise moves forward, and when the tips of the propeller are travelling at, or above, the speed of sound it lies in the plane of rotation of the propeller. The main part of the noise is at a frequency between 500 and 3000 cycles per second and is thus well within the audible range.

The intensity of the propeller noise depends chiefly on the horse-power supplied to each blade, and the speed at which these rotate; to a lesser extent it depends on the number of blades, and on their shape. H. Rudmore, A. Wayne and L. L. Beranek in America analysed the effect of these factors on the noise inside the cabin of an aircraft in flight, and showed that the level increased by about 18 decibels* if the horse-power supplied to a three-bladed propeller was doubled, and by a further 9 decibels if, as a result, the speed of the tips of the propeller increased by 100 feet per second. Bearing in mind that the difference between quiet conversation and a loud shout is of the order of 50 decibels, it is seen that the horse-power and the speed can strongly influence the noise from the propeller.

There now exists a general theory (due to W. Ernsthausen) which makes it possible to calculate the amount of noise that a rotating propeller on the ground will produce. The theory reasonably predicts the directional properties of the noise, the way in which its intensity falls off with distance, and the relative amounts of high-pitched and low-pitched sound in its composition. Ernsthausen's theory holds best when the propeller tips are rotating slower than the speed of sound, but is still reasonably valid at higher speeds. It applies, however, only to earth-bound propellers. When the plane is flying the characteristics of the propeller sound change, and there is at present no theory which can completely explain what happens under flight conditions.

NOISE FROM JET AIRCRAFT

We come now to the noise from jet aircraft. This is a subject which has only been of real concern since the end of the late war and, as a result, the experimental data is less extensive. Nevertheless, a number of most interesting discoveries have been made.

E. J. Richards and A. Powell of Southampton University, and G. M. Lilley and others at Cranfield College have shown experimentally that when the gases emerging from a jet are travelling slower than the speed of sound, the main source of the noise is at a point fairly close to the exit of the jet. M. J. Lighthill has now put forward a hypothesis in which this source is identified as a stationary "quadrupole", that is to say, four equal noise sources infinitely close together. This stationary "quadrupole" is responsible in the main for the high-frequency noise—the whine of the jet. The energy of the noise is given by an expression of the type

$$E \propto \frac{V^8 L^2}{C^5},$$

where V is the speed of the jet gases relative to the surrounding air, L the jet diameter, and C the speed of sound. It is seen that this noise goes up very rapidly as the speed of the gases increases; thus doubling the speed increases the high-frequency noise by 256.

According to Lighthill's hypothesis the "quadrupole" near the jet exit is the main source of noise when the gases are emerging at less than the speed of sound. At higher speeds it still operates, but it is found that the

* One decibel is the smallest change which the average person can detect in the intensity of a sound at the standard frequency of 1000 cycles per second. The loudness of the sound depends both on its intensity and on its frequency.

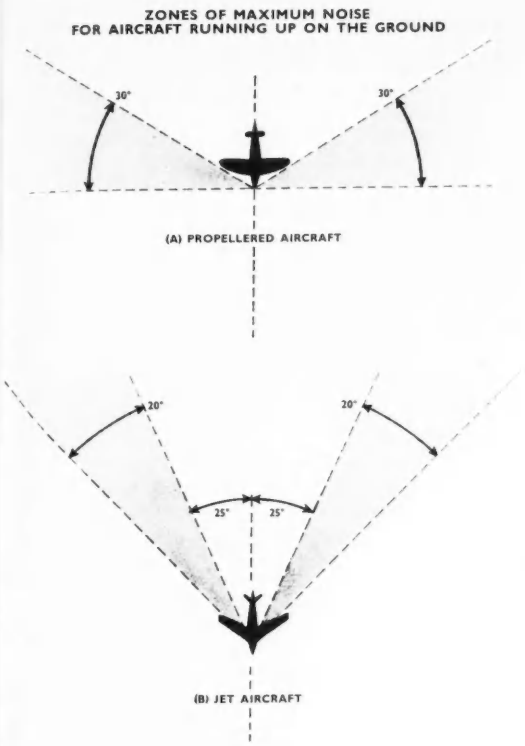


FIGURE 1

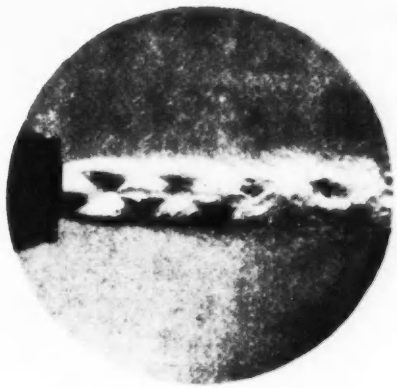


FIG. 2. The pattern of gas flow from a choked jet.

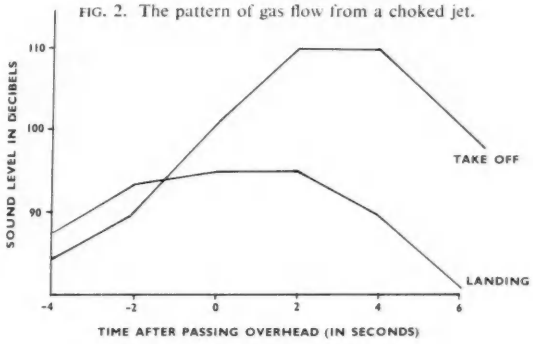


FIG. 3. Noise from the Comet at 400 ft.
(From M.O.S. Report NC 122, Pt. 3)

noise now goes up as the fourteenth power instead of as the eighth power of the speed. At still higher speeds the jet becomes "choked", the gases emerging in surges instead of in a relatively smooth stream (Fig. 2). Under these conditions the noise may increase very greatly as the twenty-ninth power of the speed. The very great increase at these high speeds is due to the development of secondary sources of noise. These arise as a result of the interaction of air eddies with the shock waves which occur in the gas stream. They appear to be in the form of moving "quadrupoles" which occur some distance downstream from the jet exit. In contrast to the stationary "quadrupole", the moving "quadrupoles" give rise to low-frequency noise. They are thought to be responsible for the thunder-like rumble heard after a jet aircraft has passed overhead.

Under normal circumstances, the height at which aircraft fly prevents their noise being a major nuisance. It is mainly when a plane is taking off, landing, or revving up its engines on the ground that it is likely to reach objectionable intensities. Besides the actual increase due to more powerful engines, the problem has been accentuated in recent years by the building of new airfields close to centres of population. This has resulted in complaints from residents in the immediate vicinity, and from those whose homes lie on the landing circuit (which may have a diameter of over 10 miles), the trouble being caused mainly by aircraft flying below 2000 feet.

Investigations have been carried out on the relative amounts of noise produced by different types of aircraft engine, and on the areas over which this noise may be a nuisance. It has been found that propeller engines may produce a noise level of up to 120 decibels at a distance of 300 feet, while jet and rocket engines give even higher levels. According to one estimate, a turbo-jet is twenty times noisier than a pneumatic drill, at the same distance. Experts of the Ministry of Supply have analysed the noise from Comet aircraft during take-off and landing. The results, as graphed in Fig. 3, show that a sound-level of some 110 decibels is recorded for about three seconds just after the machine has passed overhead at 400 feet during the take-off. Landing noise at the same height appears less severe, but since the aeroplane stays near the ground for a longer time on the landing run, the net nuisance may actually be greater.

A study on four-engined Stratocruisers was made recently at an American airport to find to what extent they constituted a nuisance. Assuming that the planes climbed at an angle of 5° to the horizontal when taking off, it was found that four regions could be distinguished. In region "A" (noise above 65 decibels) conversation

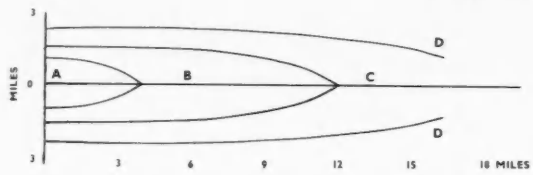


FIG. 4. The noise zones associated with a Stratocruiser.

out of doors was impossible. In region "B" (noise between 50 and 65 decibels) conversation could only be carried on by shouting. In region "C" (noise between 35 and 50 decibels) it was necessary to raise the voice, while in region "D", beyond the 35-decibel level, relatively little inconvenience was caused. The results have been plotted diagrammatically in Fig. 4. In order to translate some of the noise levels that have been quoted into everyday experience Fig. 6 will probably be found helpful. Over the audible frequency range, 200 to 10,000 cycles per second, the human voice produces a sound pressure of up to about 80 decibels. Discomfort sets in at about 110 decibels, and mechanical damage to the inner ear occurs at about 150 decibels.

The point now arises: what steps can be taken to reduce the noise from aircraft?

THE REDUCTION IN AIRCRAFT NOISE

The reduction of aircraft noise can clearly be tackled at two levels. For planes on the ground, sound screening has been tried with noticeable success. Thus at London Airport both propeller and jet aircraft have been run up close to a concrete wall about 40 feet high and 100 feet long. It was found that an overall reduction of up to 25 decibels could be achieved in the shadow of the wall. The attenuation was greatest for the high-frequency noise, and better results were obtained using high walls than when the aircraft were run into sunken pits. Portable screens, which can be placed around individual aircraft, have also been used with some success.

In the case of jet aircraft, exhaust mufflers have been tried. The basic principle is to prevent the exhaust gases from emerging horizontally, and instead to deflect them vertically upwards. In this way it has been possible to reduce the noise in some directions by a factor of 16.

FIG. 5. Nozzle with V-shaped notches.

Probably the simplest and most effective method, however, for reducing aircraft noise on the ground is to make use of the fact that the noise is not uniformly spread around an aeroplane but is concentrated into fairly well-defined zones. In the case of propeller aircraft the maximum noise occurs in a zone behind the plane of the propeller having a width of about 30°. For jet aircraft this maximum has been shown to occur in a direction between 25° and 45° to the emerging jet stream (Fig. 1). Hence by "positioning" the different types of aircraft it is possible to reduce considerably the noise reaching neighbouring built-up areas. This procedure, taken in conjunction with the use of baffle walls has already been shown to have excellent results.

Once an aircraft has taken off from the ground "positioning" and sound screening are, of course, no longer practicable. But is it possible to silence the aircraft themselves?

It has already been noted that for propeller aircraft flying at up to about 400 m.p.h. the main source of noise is the propeller and that the speed of its tips is the predominant factor producing the noise. Hence the most obvious way of silencing the machine is to reduce its propeller speed. To do this without at the same time reducing the propulsive power requires a greater number of blades per propeller. Although this leads to an increase in weight, the smaller, slower-turning, multi-bladed propeller proves to be not only less noisy than the rapidly rotating, two-bladed propeller, but more powerful—a compensation for the increased weight. Further silencing has been achieved by modifying the shape of the propeller tips; for example, sharp tips are found to be about 3 decibels quieter than blunt ones.

Significant noise reduction for jets has so far been achieved only at the laboratory stage using scale models operating under particularly favourable conditions. The findings, however, have indicated lines along which development may be hoped for.

Going back to the equation $E \propto V^8 L^2 / C^5$, it is clear that a reduction of the speed at which the jet gases emerge would greatly reduce the amount of noise. A number of ways of achieving this have been suggested, of which perhaps the most satisfactory would involve the use of a greater volume of air passing through the jet. The use of the ducted fan engine would seem to offer a practicable means of reducing the gas velocity, but this engine possesses certain undesirable features so that its adoption by aircraft manufacturers might be a matter of some difficulty. On the other hand new designs may overcome these difficulties.

But to change fundamental designs is always a slow business. It may take many years to convince manufacturers that it is worth sacrificing a little power and speed for the sake of a saving in noise. In this interim period it is likely that noise suppression by a variety of devices will be preferred. A number of these have already been suggested. It has been found for example that by having the nozzle of the jet notched instead of smooth (Fig. 5) considerable suppression of the noise

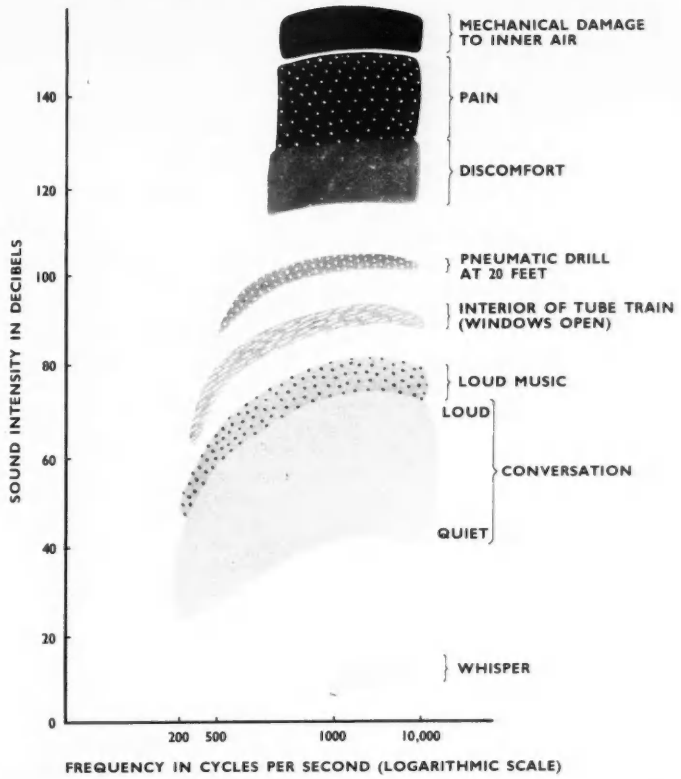


FIG. 6. The shaded areas in the diagram show how the loudness of a sound depends on its intensity and on its frequency. A sound having an intensity of 70 decibels and a frequency of 200 cycles per second is about as loud as one with an intensity of 90 decibels and a frequency of 10,000 cycles per second since both produce the same level of loudness: namely that associated with the interior of a tube train.

could be achieved. In one particular case the remarkable reduction of 15 decibels was attained. With the same end in view, vanes, teeth, gauzes and other obstacles have been introduced into the jet stream. The actual mechanism by which these devices operate has not been fully established but the net effect is that both the high-frequency and the low-frequency noise is reduced, although the effect on the latter is less noticeable than on the former.

The difficulty about the low-frequency noise is that it originates a considerable distance downstream from the jet exit. Suggestions have therefore been made that the interference from two converging jets might be the best means of breaking up the turbulence and eddy patterns in this region. As yet, however, experimental results are not available.

Injection of water into the jet stream has been tried as a means of reducing noise. A report from the National Physical Laboratory recently showed that at an injection rate of 12 lb. of water per sec. the noise of a rocket motor could be reduced by 8 decibels in both the high- and low-frequency ranges. The reduction may be due to the temperature changes involved in vaporising the water. Although the employment of such large amounts of water is unlikely to be practicable under actual flying conditions the technique has potentialities and further work is envisaged.

From what has been said it is seen that suppression of jet noise is possible. But it should be emphasised that so far most of the experimental work has been carried out only on model jets under laboratory conditions. Whether the findings will be equally applicable to full-sized engines under working conditions will only emerge when proper trials have been performed. Such trials are being planned for the near future.

The harassed *Manchester Guardian* correspondent may thus take some comfort. The Government has recognised the existence of public concern about aircraft noise, and is spending £100,000 per year on research into means of reducing it. The findings so far are encouraging.

(Figs. 2 and 6 are reproduced from E. J. Richards's paper cited in the reading list below.)

READING LIST

Handbook of Acoustic Noise Control by Wright Air Development Centre. Technical Report 52–204, published by McGregor and Werner Inc., Dayton, Ohio, June 1953.

"Aerodynamic Noise from Jets" by E. J. Richards, *Journal of the Royal Aeronautical Society*, 1953, vol. 57, pp. 318–42.

"Symposium on Aircraft Noise", *Journal of the Acoustical Society of America*, 1953, vol. 25, pp. 363–442.

W. Ernsthausen, *Zeit. angew Math. und Mech*, 1951, vol. 31, No. 1/2, pp. 20–35 (summarised in English in the above symposium, p. 367).

AN ECHO-SOUNDING BIRD

PROF. DONALD R. GRIFFIN

Professor of Zoology, Biological Laboratories, Harvard University

In his account of his explorations in South America 155 years ago, the German scientist Alexander von Humboldt described a remarkable cave-dwelling bird he found there. The bird is called the guácharo (Spanish for "one who cries and laments"). Humboldt visited the great Cavern of the Guácharos near the town of Caripe in the highlands of Venezuela.

The guácharo, he reported, was "the size of our chickens", with a wingspread of three and a half feet, and had "the mouth of a goatsucker, the bearing of a vulture . . . an extremely strong beak furnished with a double tooth" and blue eyes which were "dazzled by the daylight". A nocturnal bird, it quits the cave at nightfall to feed on fruit. The bird is covered with extensive deposits of fat, and it was and still is prized for its oil—a transparent, odourless, butter-like food that was said to keep for a year without becoming rancid. (Humboldt named the bird *Steatornis caripensis*—the oil bird of Caripe.) Once a year the Indians went into the cave with long poles, knocked down the guácharo nests from the high roof of the cave and killed several thousands of the nestlings. Then they extracted the oil by melting down the squabs in clay pots over brushwood fires outside the cave.

One of the most remarkable attributes of the guácharo, as Humboldt observed, was the great "volume of its voice". He wrote: "It is difficult to convey any idea of the frightful noise which thousands of these birds produce in the dark portions of the cavern. . . . The sharp and piercing sounds of the guácharos are reflected from the rocky vault, and the echoes reverberate from the depths of the cavern."

This part of Humboldt's account has intrigued me for some time. Here is a bird that flies about in dark caves uttering sharp cries. Bats, which also live in caves, have an echo system of navigation based on high-pitched cries inaudible to human ears.

Does the guácharo guide its flight in the darkness by means of a similar sonar-like system in the audible range? I resolved to find out, and so a year ago I retraced Humboldt's footsteps to the Cavern of the Guácharos in Venezuela.

The trip was made possible by the generosity of William H. Phelps, Jr., the well-known ornithologist of Caracas. We took along a portable tape recorder and the same apparatus that we use to detect and analyse the high-frequency sounds of bats. In 1953 we had a much more gentlemanly trip to the cave than that described by Humboldt in 1799. Humboldt and his botanist companion Aimé Bonpland had been obliged to climb through a heavy tropical forest, criss-crossing a raging torrent on the way up. We debarked from an airliner at an airport 50 miles from Caripe. Near Caripe was a pastel-tinted "Hotel El Guácharo". We were driven in an automobile up a gravel road to the very mouth of the cave. There we were greeted by a custodian and a crew of guides eager to lead us through the cavern. Indeed we were told that electric lights were soon to be installed in the cave to save tourists the inconvenience of carrying flashlights.

The oil birds were still there in considerable numbers, now protected by the government. Our first concern was to determine the degree of darkness in which the birds could fly. We therefore walked deep into the cave, past a twilight zone full of nesting birds to a place where turnings in the passage shut out the daylight. Humboldt had described his penetration into the cave in the following words: "We had had great difficulty in persuading the Indians to pass beyond the anterior part of the cavern, the only part which they visit annually to gather fat. . . . The natives attached mystical ideas to this cave inhabited by nocturnal birds. They believe that the souls of their ancestors reside at the bottom of the cavern. . . . To go to join the guácharos is to rejoin one's fathers, is to die. . . . We walked in a thick mud to a point where we saw with astonishment the development of a subterranean vegetation. The fruits which the birds carry into the cave to feed their young germinate wherever they fall into the mould which covers the calcareous incrustations. Blanched stalks provided with some rudiments of leaves grew to a height of as much as two feet. . . . These traces of organisation in the midst of darkness aroused a lively curiosity in the natives, otherwise so stupid and so difficult to excite. They examined [the blanched shoots] in silent contemplation inspired by a place which they seemed to dread. . . . The missionaries, despite their authority, could not persuade the Indians to penetrate farther into the cavern. As the roof of the cavern became lower, the cries of the guácharos became more piercing. It was necessary to give in to the pusillanimity of our guides and retrace our steps."

We also found ourselves walking through a meadow of white shoots, just as Humboldt had described. About 2000 feet from the entrance we arrived at a large chamber called *El Barrial*, which Humboldt apparently did not reach. Picking reasonably dry and comfortable rocks to sit down upon, we turned off all our lights and waited for our eyes to adapt to the darkness so that we could tell whether there was any natural light here. I also set up a camera facing the direction of the entrance, with its entire lens mount removed and its Super XX film directly exposed to whatever daylight might possibly penetrate to *El Barrial*.

Over our heads guácharos circled noisily and called back and forth to one another from ledges 75 to 100 feet high. We waited 25 minutes to assure complete dark adaptation of our eyes. I must admit that this wait in the clamorous darkness was an uneasy one, and I am sure more than one finger wandered wishfully toward a flashlight switch. I could only feel the deepest sympathy for the Indians of Humboldt's party and wonder what

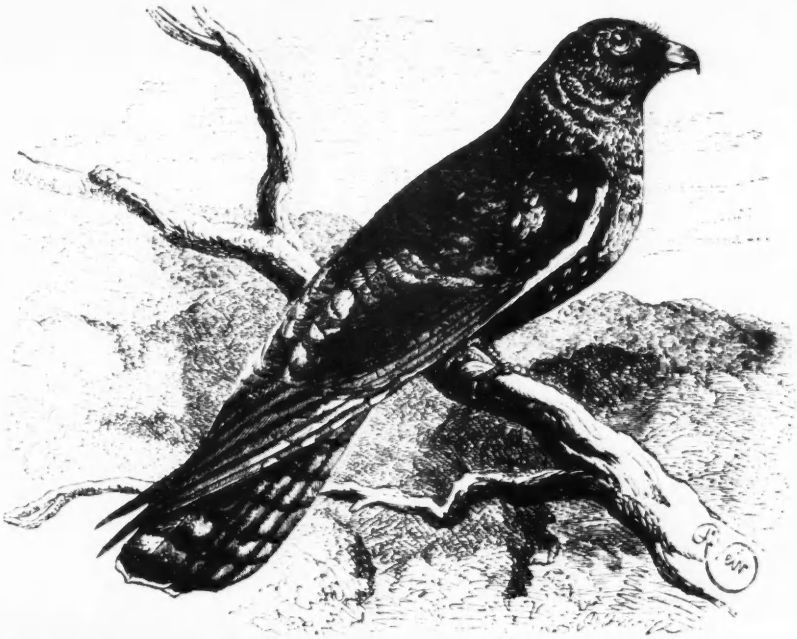
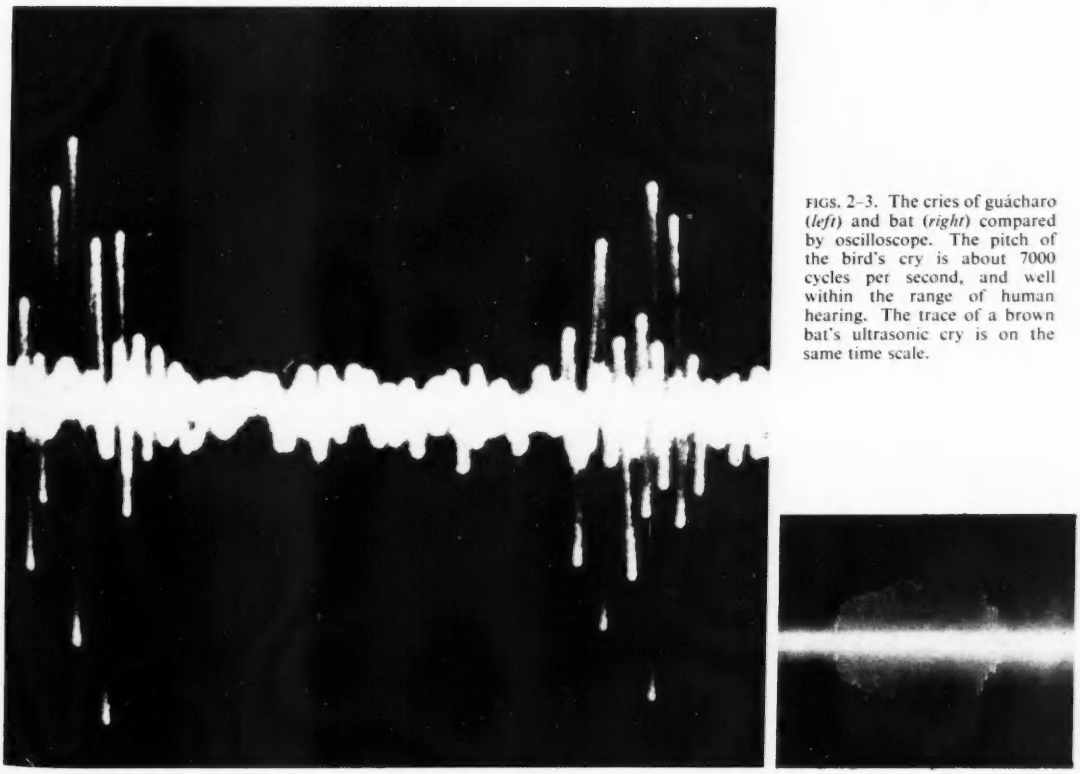


FIG. 1. The guácharo was depicted in A. Brehm's *Illustriertes Thierleben*, published not long after Humboldt's 19th-century description. The bird has a wingspread of three and a half feet.



FIGS. 2–3. The cries of guácharo (*left*) and bat (*right*) compared by oscilloscope. The pitch of the bird's cry is about 7000 cycles per second, and well within the range of human hearing. The trace of a brown bat's ultrasonic cry is on the same time scale.

FIG. 4. Blanched plants sprout in the dark Cave of the Guácharos. They grow from seeds in the droppings of the birds. These plants would grow to a height of 50 ft. in the light.

their reactions would have been if he had ordered them to extinguish their torches and listen to the guácharos in total darkness.

At the end of 25 minutes we were all agreed that no light was to be seen in any direction. Furthermore, the film, which had been exposed for nine minutes, later confirmed this by showing no evidence of light upon development. Our first question was thus conclusively answered: the guácharos did fly in total darkness.

Now we had to determine whether the squawks and shrieks the birds gave forth almost constantly were used for orientation. Bats employ very brief bursts of ultrasonic sound for their echo-locating system. Some of the sounds uttered by the guácharos were rather sharp, short clicks, but these clicks formed only a small part of the sounds we heard during our stay in the cave.

Phelps had noted on a previous visit that the birds made particularly striking noises as they flew out of the cave for their night's hunting. We therefore set up a microphone at the cave entrance. We had to place it on the pinnacle of a rock 15 or 20 feet high, because the birds generally flew near the ceiling some 75 to 100 feet above our heads. Lower down on this rock were arranged amplifiers, a variable electronic filter, a cathode-ray oscillograph, a tape recorder, a 16-millimetre camera to photograph the cathode-ray traces and a storage battery plus vibrator to provide 60-cycle power.

At twilight the guácharos began to fly out. I could scarcely believe these were the same birds we had heard inside the cave that afternoon. For now there were no squawks, clucks or screeches. Instead there came out of the gathering darkness a steady stream of the sharpest imaginable clicks. Each click had a duration of only one to two thousandths of a second—about the same length as the ultrasonic signals of bats. Well into the night the stream of birds and the barrage of clicks continued undiminished. During the whole evening we heard no more than half a dozen of the longer calls and screeches that had predominated inside the cave during the day.

We still lacked any direct evidence that these clicks were actually emitted to locate objects in the birds' path by the echo. Perhaps the clicks were only call notes or symptoms of some other avian emotion, the nature of which we could not guess. Accordingly we trapped three birds in a net and took them to an improvised dark-room to make further tests.

The first test was to plug their ears. When both ear canals were tightly stopped with absorbent cotton and cellulose acetate cement, the birds were completely disoriented. In the dark they banged into the walls whenever they took wing. But when the plugs were removed they were again able to fly about in the dark-room without colliding with anything. They also flew without difficulty when the light was turned on even if their ears were plugged.

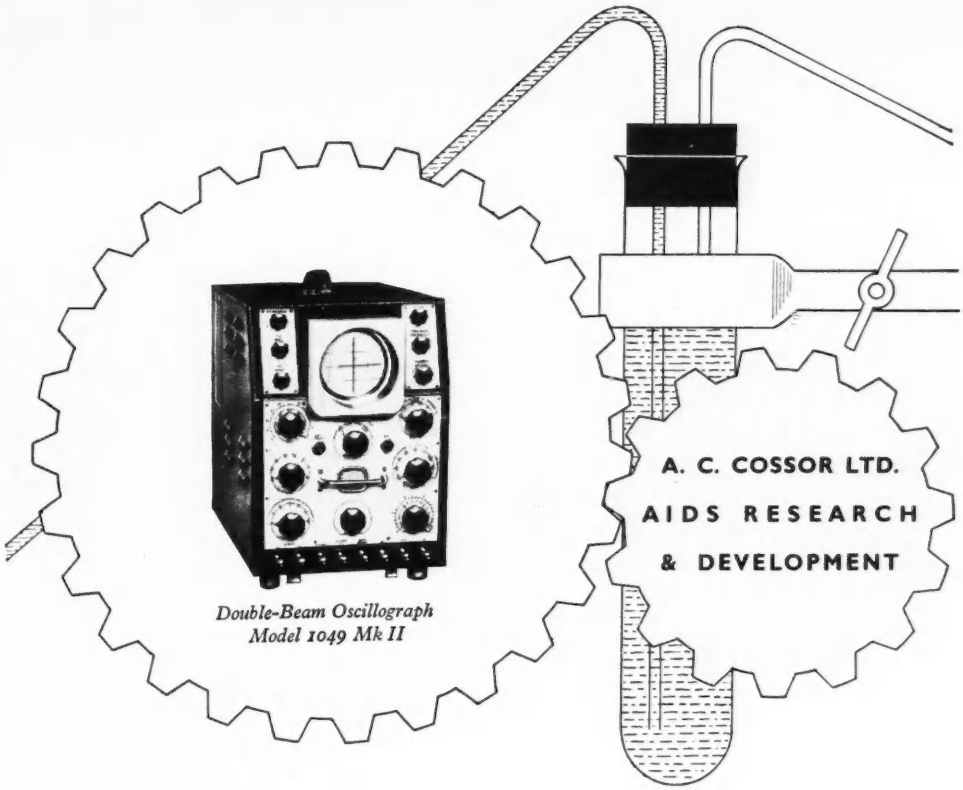
Even these limited tests were sufficient to show that these birds, like bats, use clicks to avoid obstacles in the dark by echo-location. Unfortunately we were not able to carry the tests much further, and many interesting questions are still unanswered. For example, we do not know how small an object the oil bird can detect. Since the wavelength of its clicks (about five centimetres) is much longer than that of a bat's ultrasonic sounds (less than one centimetre), the guácharo must fail to detect obstacles which a bat could easily locate.

The oil bird's sounds have a frequency of about 7000 cycles per second—well within the range of human hearing. The question arises: If the oil bird can use such sounds to guide it in the dark, could not a man develop the same skill? The highly perfected human hearing apparatus would appear quite capable of achieving the type of sound analysis necessary for echo-location.

Blind men do indeed achieve a considerable skill in finding their way about, and this ability is often called "facial vision". But the skill is largely lost if the blind man's ears are tightly stopped or if loud noises interfere with the hearing of faint echoes. Very possibly man could develop the echo-locating ability by using short pulses of sound. Since sound travels roughly one foot per millisecond, the pulse should be no longer than one or a few milliseconds to return a distinguishable echo at a distance of a few feet. Perhaps properly designed click generators or similar sources of pulsed sound could enhance the ability of blind people to find their way about.

The pragmatic experience of blind men, unconsciously using the taps of a cane, footsteps or other sounds to guide them, may already have produced as much skill in echo-location as the human auditory mechanism allows. But it might not be amiss to see what we can learn from the guácharo and other flying animals which have developed more precise systems of echo-location.

(This article is reprinted from "Scientific American" by arrangement with the Editor.)



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THE BREATHING MECHANISM OF INSECTS

PROF. V. B. WIGGLESWORTH, C.B.E., M.D., F.R.S.

Unit of Insect Physiology (Agricultural Research Council), Department of Zoology, Cambridge

It has been customary in the past to regard the insect as a creature with a relatively simple organisation. From time to time physiologists have turned to the study of insects in the hope that they might find in them a living machine free from the baffling complexities of the higher vertebrates. The celebrated Spanish neurologist Cajal, hoping to understand the nervous basis of vision "in relative simplicity", turned to the insect eye. But after studying it for two years he wrote: "The complexity of the nerve-structure for vision is even in the insect something incredibly stupendous. . . . The intricacy of the connexions defies description. Before it the mind halts, abased."

Students of other systems have met with similar disappointments: what appeared at first sight to be simple, has revealed on closer acquaintance many unexpected complexities. That is certainly true of the respiratory system. The breathing mechanism of the insect was discovered by Malpighi and described in his classic work on the anatomy of the silkworm published by the Royal Society in 1669. This system, called the tracheal system, consists of a number of branching tubes which open along the sides of the body through a series of spiracles and which run inwards conveying air directly to every organ (Fig. 1). Provided the insect is fairly small this is indeed a simple and efficient means of supplying the body with oxygen.

Furnished with a system of this kind the insect no longer uses its skin for respiration. It has been able to develop a body-covering which is almost completely impermeable to oxygen and to water. The insects have thus been able to colonise the dry land and to become the dominant group of animals on the earth today. But naturally the tracheal system remains permeable to oxygen; it must therefore of necessity remain permeable also to water; and if the spiracles were kept open continously, so much water would be lost that in dry surroundings the insect would quickly die of desiccation.

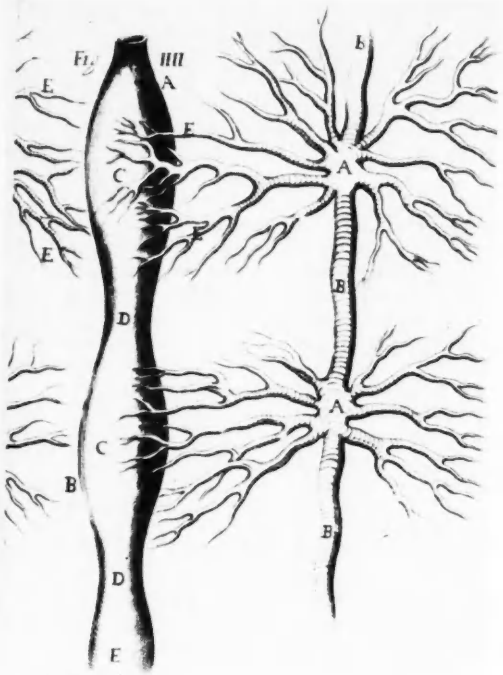
It was discovered in the last century that each spiracle has a more or less elaborate closing mechanism, sometimes of most elegant design (Fig. 2). It was supposed that the purpose of these sphincters was to exclude dust and other foreign matter from the tracheal system. But their true function was pointed out by Hazelhoff about twenty-five years ago. It is to conserve water. The insect keeps its spiracles tightly closed most of the time and only opens them sufficiently often to admit the oxygen which it requires. If it is induced to keep its spiracles permanently open (by exposure to air containing carbon dioxide) it quickly dries up. For example, the blood-sucking bug *Rhodnius* will live for some weeks without food in a desiccator over sulphuric acid; but if 5% of carbon dioxide is present in the air, it loses about 12% of its weight in a day and is dead from desiccation within forty-eight hours.

The spiracles are worked by muscles which are supplied by nerves coming from the central nervous system. The nerves are connected with respiratory centres situated in the brain and ventral nerve cord, and these centres control the opening and closing of the spiracles in accordance with the needs of the insect. This process can be readily studied in the flea; for this is a small insect, flattened from side to side so that it can be held below a cover-glass in a small gas chamber, while the opening and closing of the spiracles are observed by transmitted light under the microscope. By a simple arrangement of switches operated by the feet it is a simple matter to record on a revolving drum the opening and closing of the spiracles in response to changes in the gas mixture or after muscular activity in the flea.

There are ten spiracles on either side of the flea (Fig. 3); but not all of these come into operation under all circumstances. In an active flea at the height of digestion and egg-development all the spiracles may open. But in the fasting flea at rest the entire respiration may be effected through the last spiracles, the eighth spiracles of the abdomen. This pair of spiracles shows a fairly regular rhythm of opening and closing: it may remain open for five to ten seconds and then remain closed for a similar length of time. If the flea struggles for a few moments, this spiracle may remain open for half a minute or so before the original rhythm is resumed (Fig. 4).

This rhythm of opening and closing of the spiracle is controlled in two ways: carbon dioxide gradually accumulates within the body and the acidity which it produces serves as a stimulus to the respiratory centres in the nervous system and causes them to open the spiracles. At the same time, as the oxygen in the tracheal system is used up, the products of metabolism are incompletely oxidised; substances such as lactic acid begin to accumulate and they too stimulate the respiratory centre to open the spiracle. Thus both carbon dioxide excess and oxygen lack leading to the formation of acid substances act together as stimuli to the respiratory centres. Hence the addition of 2% carbon dioxide to the air causes permanent opening of the spiracles (Fig. 4A); and if the flea is exposed to a gas mixture containing only 3·2% of oxygen in nitrogen it opens and closes its spiracles continuously at a rapid rate (Fig. 4B). It is interesting to observe that if the flea is placed in pure oxygen it keeps its spiracles closed for a much longer time—often about half a minute. But when it does open them they remain open also for a much longer period. That is because so much carbon dioxide has accumulated during the closed period that it requires a relatively long time to diffuse out (Fig. 4B).

It will be noticed that in the flea the tracheae from all the spiracles are linked together to form a continuous system. That is so in all insects except the most primitive. It means that while the spiracles are closed oxygen



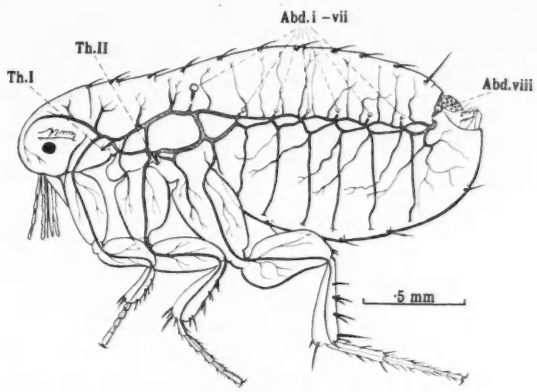
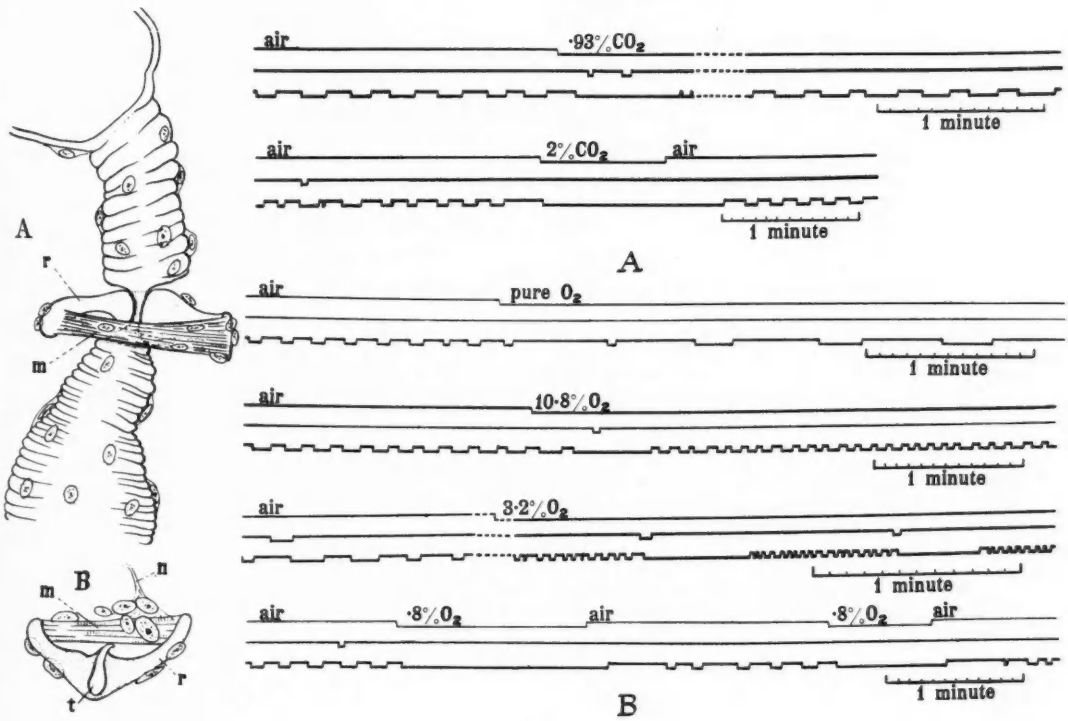


FIG. 1 (*top left*). A part of the tracheal system of the silkworm, from the original figure by Malpighi (1669).

FIG. 2 (*bottom left*). A, the spiracle and trachea of the flea showing the closing mechanism by which the trachea is occluded. This consists of an elastic rod (*r*) and a muscle (*m*). B, transverse section through the closing mechanism showing the nerve (*n*) supplying the muscle, and the trachea (*t*) lying in a cleft in the flexible rod.

FIG. 3 (*top right*). The flea's tracheal system and spiracles (two thoracic, Th. I and II, and eight abdominal, Abd. i–viii).

FIG. 4 (*bottom right*). Records showing the opening and closing of the eighth abdominal spiracle of the flea. In each tracing the upper line shows the change in gas mixture, the second line shows the periods during which the flea struggled, the lower line shows the opening (downwards) and closing of the spiracle.



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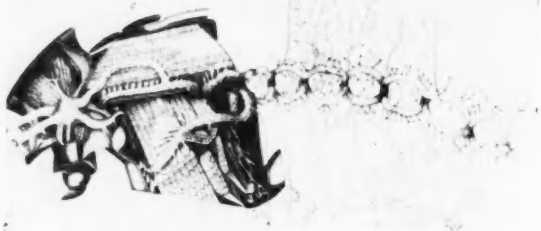

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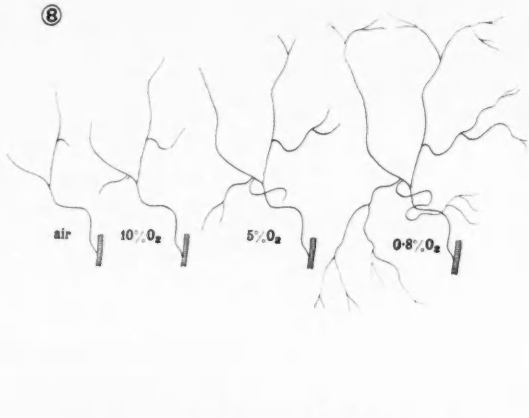

FIG. 5. Part of the tracheal system of the cockchafer showing the numerous "air sacs", from an illustration by Strauss-Durckheim (1828).

FIG. 6. Tracheal supply to the wing lobe of a young cockroach, injected with cobalt sulphide.

FIG. 7. Tracheal system of the bed bug injected with cobalt sulphide. Note the rich tracheal supply to the sucking muscle between the eyes.

FIG. 8. A small trachea and tracheoles as seen in the abdomen of a living flea examined by transmitted light under the microscope. When the insect is in air the terminal parts of the tracheoles contain liquid and are invisible. As the oxygen in the air is reduced the liquid is removed progressively, the tracheoles fill with gas and become visible.

FIG. 9. A, three large tracheal branches supplying the upper surface of the abdomen in the bug *Rhodnius*. The middle trachea is cut at X. B, the position a week later: the tracheoles from the upper and lower tracheal branches have migrated into the region without a tracheal supply, drawing the tracheae after them.

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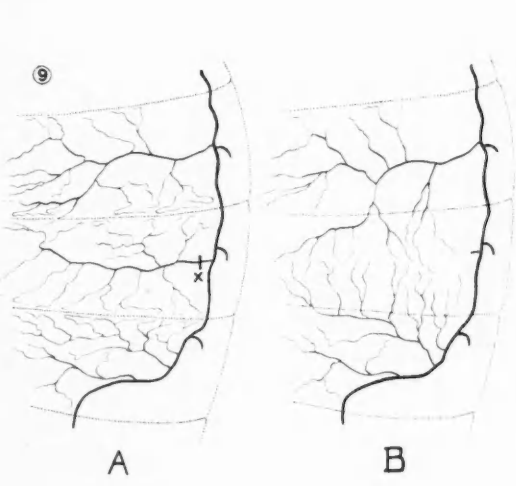

can flow to any part of the body which requires it, and it can be renewed throughout the system by opening a single pair of spiracles.

This system, in which the insect is dependent wholly upon diffusion for its supply of oxygen, serves well enough for small insects, or insects that are relatively inactive. It does not suffice for large and actively flying insects. These ventilate the tracheal system mechanically by compressing the tracheae and pumping the air in and out of the spiracles. The mechanism is much like that of the human lung except that in the insect compression is the active process, brought about by special muscles, while the expansion which leads to the filling of the system with air is often a passive process resulting from the elasticity of the body wall.

This pumping process is likewise controlled by respiratory centres in the nervous system. It is brought into action only during activity when the simple process of diffusion fails to supply enough oxygen. Those insects which make use of this active ventilation of the tracheal system usually have the capacity of the system increased by the addition of thin-walled "air sacs" which are easily compressed (Fig. 5). Indeed, the system now shows a remarkable resemblance to a lung.

But in the most active phases of the life of the insect even this system may prove inadequate to provide an abundance of oxygen to the muscles which operate the wings. The pumping movements are then combined with an elaborate rhythm of opening and closing of the spiracles which drives a current of air through the tracheal system, inwards through the spiracles of the thorax and then backwards to pass out through the spiracles of the abdomen. At the same time the contractions of the flight muscles compress and ventilate the dilated tracheae or air sacs which lie between them. We have here a respiratory system which is even more elaborate than that of man.

All these elaborate arrangements for the ventilation of the tracheal system serve to renew the air only in the larger trunks; the supply of oxygen to the fine endings is still dependent upon diffusion. In recent years we have developed a method of injecting the tracheal system which has enabled us to learn much that is new about the endings of the tracheae and their physiology.

This method consists in filling the tracheal system with cobalt sulphide. This is done by exposing the insect in a vacuum, immersing it in a strong solution of cobalt naphthenate in kerosene and then releasing the vacuum. After washing away the cobalt naphthenate adhering to the surface the insect is gassed with hydrogen sulphide, and the entire tracheal system, including the finest branches, becomes filled with a dense black precipitate (Figs. 6 and 7).

The tracheae branch repeatedly, becoming smaller and smaller until they are reduced to a diameter of about 1·5–2·0 microns. Then they end abruptly by giving off one or two "tracheoles". These are very thin-walled tubes, usually about 300 microns (0·3 mm.) in length, each of which is formed within the cytoplasm of a single elongated cell. The tracheoles usually start with a diameter of about 0·8 micron and taper gradually to end blindly at a diameter of 0·1 or 0·2 micron. They may be branched.

In the living insect the endings of the tracheoles commonly contain fluid for a variable distance at their extremities. The forces which control the extent to which this liquid rises up the tracheoles cannot be discussed fully here; but the movements of the liquid are certainly influenced by changes in osmotic pressure in the body fluid in which they are bathed. In a living insect, such as a mosquito larva or a flea, it is easy to see with the microscope that many of the tracheoles appear to end abruptly not far from their point of origin (Fig. 8, "air"). That is because the transmitted light is totally reflected from the small tubes where they contain air, whereas they are translucent and invisible where they contain fluid. If the insect is caused to struggle while it is cut off from the air (for example, by surrounding it with water as it is lightly held down beneath the coverslip) there is an accumulation of unoxidised substances in the blood. This leads to an increase in the osmotic pressure of the blood, fluid is extracted from the tracheoles and the column of air moves down towards their terminations (Fig. 8, 0·8% O_2). This process will have the effect of improving the supply of oxygen to those points where it is most needed.

The tracheal supply to the different organs varies according to their oxygen requirements: some are very richly supplied, others only sparsely. It has recently been found that the supply can be adjusted during the life of the insect according to its needs. If a large trachea is cut so that a region of the body is deprived of its oxygen supply there is an exaggerated growth of new branches from neighbouring tracheae which make their way into the oxygen-deficient zone. And if the insect is reared in an atmosphere containing less oxygen than air, say in 7% oxygen in nitrogen, there may be a general increase in the richness of the tracheal supply to all parts of the body.

Since the entire tracheal system has a cuticular lining, this new growth of tracheae can take place only when the insect moults, for at this time the lining of the tracheal system is shed along with the cuticle over the surface of the body. But even before moulting occurs there is a partial restoration of the tracheal supply when a tracheal branch is cut. This is brought about by the *migration* of existing tracheoles into the region that has been deprived of its oxygen supply (Fig. 9). Apparently the tips of the tracheoles are sensitive to oxygen-lack (or to some of the chemical products of oxygen-lack) and by amoeboid movement they creep towards such regions pulling the tracheae after them. Movements extending up to at least half a millimetre have been observed. The more closely the tracheal system of insects is examined the more complex does its physiology become.

HILL-WAVE CLOUDS

F. H. LUDLAM, D.I.C.
Department of Meteorology, Imperial College of Science and Technology, S. Kensington

In stormy weather mountain clouds contain powerful vertical currents and severe icing conditions which may have caused many aircraft crashes. To lessen these hazards by learning more about them, meteorologists are studying the effects of mountains upon the winds and testing their ideas by observing the isolated clouds which form over mountains in otherwise fair weather. This article discusses some of the remarkable features of these clouds and describes a particular example of one of their spectacular forms.

In many parts of the world there are mountain ranges which have a dominating effect upon the climate of the neighbouring lands. This influence is especially strong when the mountains extend across the prevailing winds and obstruct their free passage. The atmosphere usually resists upward and downward displacements, and the winds negotiate a small obstacle by squeezing sideways rather than by climbing over it. However, when a strong current encounters mountain ranges which extend across its path for many miles, the air may be forced to ascend, sometimes for several thousands of feet, so that the mountains become shrouded in dense clouds.

The glider pilot, whose success depends upon his skill in finding upward movements in the air, has learnt how to soar to great heights in the up-currents over mountains. During the war, flights to heights of about seven miles were made over the Alps, and more recently even higher levels have several times been reached over the Sierra Nevada, in California. Of course, the glider pilot chooses fair weather for his flights, and he avoids the equally strong down-currents which lie in the lee of the mountain ridges. But these down-currents can become a great hazard to the pilot of a powered aircraft when his course over the mountains lies nearly parallel to a long ridge. In them the air may sink at more than a thousand feet a minute, so that the aircraft could quickly be brought perilously close to the peaks unless the pilot notices and corrects the descent. In bad weather the aircraft may have become heavily iced in passing through dense clouds, so that it becomes too sluggish to respond in time, or so strained that if it enters a commotion of winds close to the peaks the wings fracture, and there is sudden disaster. Because of the concern over mountain weather as a cause of aircraft crashes, meteorologists are being encouraged to study the effect of mountains on the wind.

THE STUDY OF AIR-FLOW OVER MOUNTAINS

As with most meteorological problems, a first examination of the theory of the effect of a mountain upon the wind shows it to be very complicated, and some drastic simplifications have to be made before any progress is possible, as otherwise the mathematics is too difficult. It is customary to suppose that the air-flow is steady and smooth, and is directed across a single long ridge of some simple shape. It is further assumed that the air flowing over the ridge is affected by it only for a time, short compared with a day, so that the effect of the earth's rotation upon the motion can be neglected. The disturbances produced by the ridge are treated as small perturbations in the flow.

The first calculations of the disturbed flow to be made along these lines were those of the German worker, Lyra, in 1940. He took into account the spring-like properties of the atmosphere, which make it behave quite differently from the air in ordinary wind-tunnel experiments, and he assumed the wind speed in the current approaching the ridge to be the same at all heights. The ridge was supposed to have a rectangular cross-section. Lyra obtained the remarkable result that a series of waves was set up over and down-wind of the ridge, whose size decreased steadily with distance downstream.

The theory thus made an encouraging start, for the existence of such a train of waves in the lee of a ridge is sometimes very beautifully demonstrated by a series of *lee-wave clouds*. These are seen when the air generally is free of cloud, but damp enough for condensation to occur where the air lifted into the wave crests is chilled by expansion under the reduced pressure (Fig. 1). More commonly only a solitary *hill-wave cloud*, formed over the ridge or mountain peak itself, is seen. We may then suppose either that the following lee-waves are too small to ensure a renewed condensation, or that the lee-wave train is not present at all. Lee-wave clouds are usually seen as long, parallel bars of cloud lying across the wind direction, suggesting that they have been caused by a long ridge (Fig. 2), but hill-wave clouds have oval or lens-shaped outlines, suggesting that some particular peak is responsible for their formation (Fig. 3). In windy weather, wave clouds are a remarkable sight, because they remain poised over the mountains: the air passes through them, and cloud

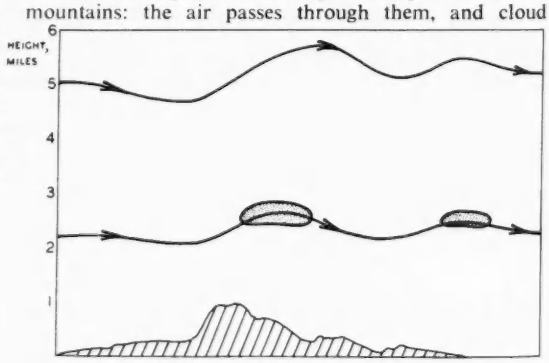

FIG. 1. Formation of wave clouds. The diagram shows two possible streamlines in air moving across a ridge, with lee waves behind the ridge. Where the air rises it is cooled, so that clouds may form in the wave crests. The up- and down-motions may be greatest at high levels, but in this example the air there is supposed to be rather dry, so that no high wave clouds form.

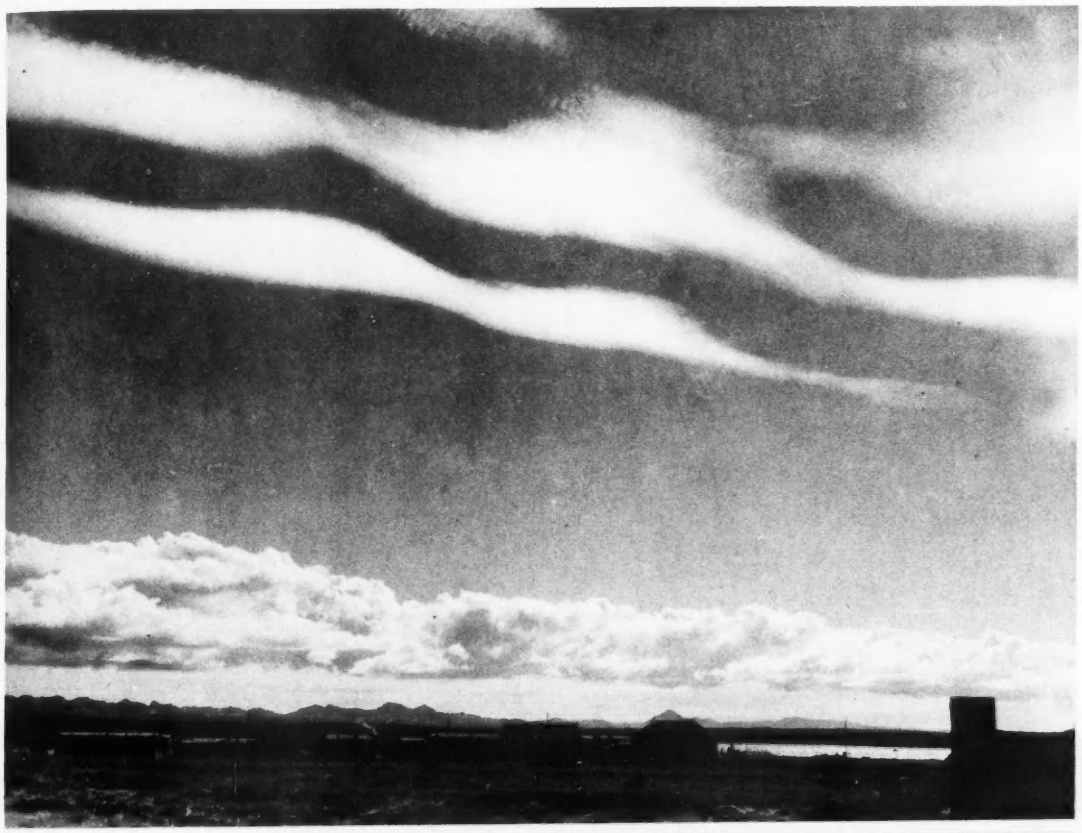

FIG. 2 (*above*). Lee wave clouds (*upper part of picture*) in Iceland, formed in the lee of the distant hills.

FIG. 3. Isolated wave clouds over the South Downs.

FIG. 4. A high cloud streamer over North Wales. The clouds form continually at the right-hand end of the streamer, and grow rapidly as they move to the left.

details can often be seen to form at one edge, sweep across the cloud and evaporate on the lee side.

A less satisfactory conclusion of the theory was that the size of the up- and down-motion in the air waves increases steadily with height above the mountain, which seems unlikely to be true. The French investigator, Queney, showed that this conclusion was a result of the initial assumptions on which the theory was built. He chose a ridge with a smooth, not a rectangular outline, and then showed that in consequence the lee-waves predicted by the theory are very small and confined to low levels. Subsequently, Scorer has greatly advanced the theory by the series of studies he has made in England since the war. He found that to construct a more realistic theory it is necessary to take into account the way in which temperature and wind speed change with height inside air-streams.

Scorer's criterion for the occurrence of lee-waves is that there should be a substantial decrease with height in the value of a quantity which depends mainly upon the rate of temperature decrease upwards and the square of the wind speed; the latter is generally the more important factor. In our country and places with a similar climate the wind commonly increases greatly with height (up to near the tropopause) without much change in direction: Scorer therefore reaches the interesting conclusion that, especially where mountain ridges lie across the prevailing westerlies, the air must very often contain lee- and hill-waves. This is certainly supported by the experience of glider pilots and the frequent occurrence (even in regions which would not be called "mountainous") of wave clouds or of clouds obviously modified by wave motions. Nevertheless observations show that the magnitude of the waves varies greatly in apparently rather similar air-streams, and while this might be due partly to the confusing complexity of natural hill shapes we are also led to look for some subtleties in the character of an air-stream which may have a strong influence on the development of waves.

DIURNAL CHANGES IN WAVES AND WAVE CLOUDS

One of the striking features of wave clouds is their habit of forming during the night, or for an hour or two about sunrise or sunset, rather than in the middle of the day. Glider pilots, who usually are active during the day rather than in the night or at sunrise, have become so accustomed to the strong development of waves about sunset that they call them by the special name of "evening waves". High-level wave clouds have

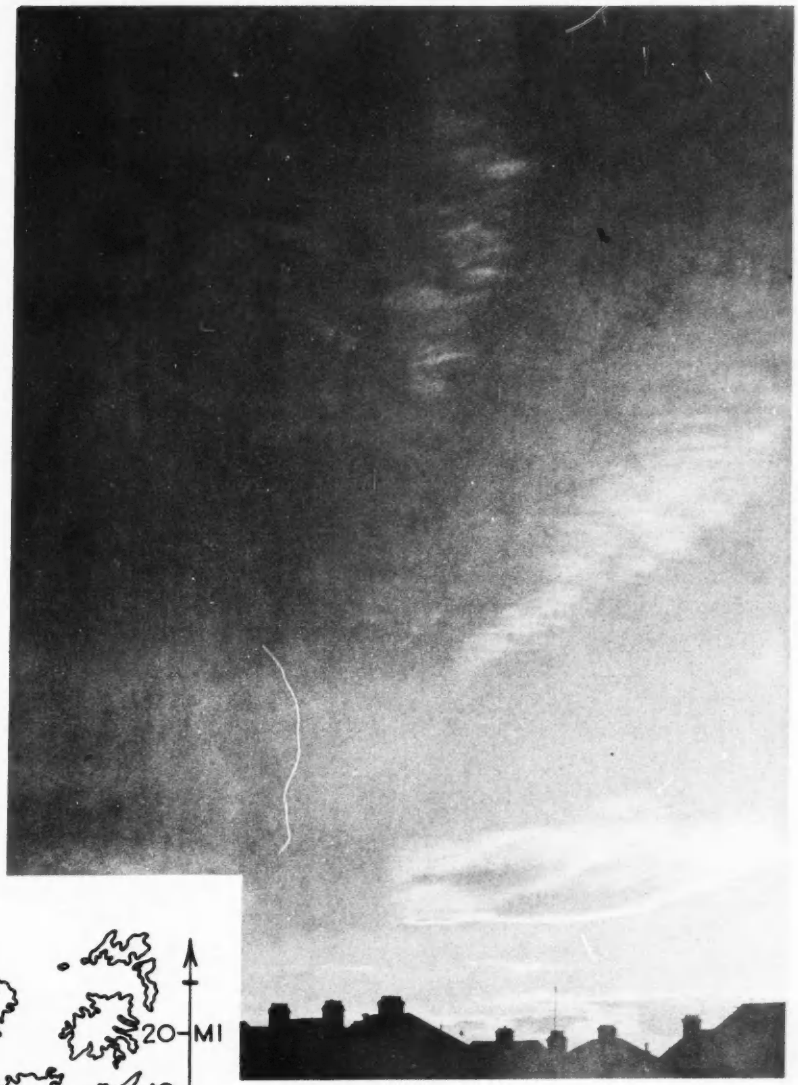

FIG. 5 (*right*). View westwards from Dunstable, 1924 GMT, July 19, 1952. Near the horizon are remnants of low-level convection clouds. Above them in the lower right of the picture is a great hill-wave cloud in the first stages of its growth. Its nearer edge is being carried rapidly by the wind towards and a little to the right of the observer, but its far edge is held in the same place by a continuous cloud formation.

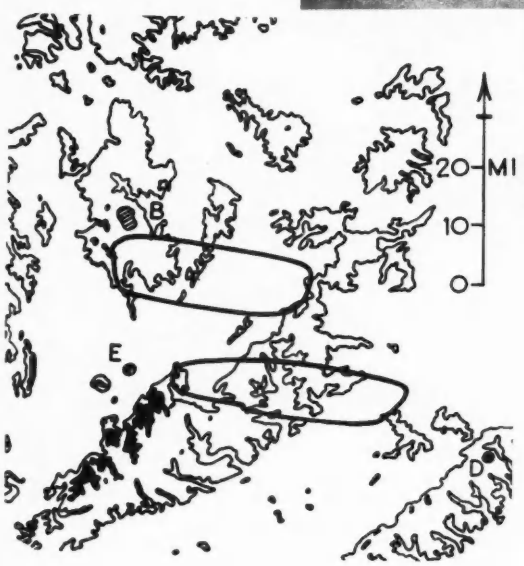

FIG. 6 (*left*). The positions of the two great hill-wave clouds at 1943 GMT; the thick lines indicate their boundaries. The 400-feet ground contour is drawn; ground above 800 feet is shown in black (the clouds were at about 25,000 feet). Also marked are the positions of Birmingham (B), Evesham (E), and Dunstable (D), the observing point.

a property which makes this behaviour very impressive, and this is their tendency to stretch far across the sky down-wind of the mountains, in great streamers. When they form at sunrise or sunset on fair days they are often lit in fiery colours so that even lowland people can hardly fail to notice them.

This streamer formation is in itself an interesting problem, for most wave clouds are not bigger in horizontal extent than the mountains which cause them. It has been suggested that there may be an extension many miles down-wind if the droplets in the wave cloud freeze and turn into crystals, for at low temperatures these can survive and even grow in air which behind the mountains has returned to its original level and is no longer quite damp enough to sustain a cloud of liquid droplets. Because the droplets which form in a wave cloud are small and are carried through it by the wind in only a few minutes, appreciable numbers do not freeze unless the temperature approaches −30°C or −40°C, and so these vast ice tails appear only when the clouds form at heights of some twenty or thirty thousand feet. I call the wave clouds which extend far beyond the mountains "great hill-wave clouds" to distinguish them from the smaller wave clouds which remain over the mountains. Fig. 4 shows such a cloud formed over hills in North Wales. Ice clouds like these often form great bands which stretch from the Welsh hills right across England into the North Sea.

Some great hill-wave clouds evidently contain no ice crystals: they look lower, and, instead of being fibrous like typical ice clouds, have a more compact texture with little dapples and billows. Near the sun they have bright iridescent colouring, which shows them to be composed largely, if not wholly of water droplets. This implies that the air which has risen in the hill wave takes a long time to return to its original level, and some of Scorer's calculations suggest that this may well happen sometimes. However it may be, on this account or because of the freezing of droplets, the great hill-wave clouds reach far from the hills over which they form, spreading rapidly in the strong winds at their high level. Even though they may form for only an hour or two they can cover a big region, and, because of their height, be observed from afar. Perhaps this is why in many places high clouds are seen early and late in the day more often than at other hours.

FIG. 7 (1950 GMT) and FIG. 8 (1959 GMT) show how the clouds continued to grow.

FIG. 9. 2027 GMT. The great hill-wave clouds, lit from beneath by the setting sun, showing strands of falling ice crystals trailing back and to the left.

FIG. 10. 2102 GMT. An hour after sunset bands of low cloud have formed and are seen silhouetted against the twilight sky. Only traces of the great hill-wave clouds remain.

Except close to the ground the diurnal changes in the character of an air-stream are hardly noticeable, and so the tendency for wave clouds to appear at about sunrise and sunset must be due to some peculiarity in the surface-layer winds at these times. Scorer emphasises that close to a mountain the air-flow may not be smooth, as assumed in all the theories. The mountains may have a kind of disturbed wake, so that there is no steady motion and the flow at higher levels is hardly affected. Wakes form most readily if there are abrupt rather than smooth ground slopes, and especially if convection occurs in the surface layers of air. He therefore attributes the daytime disappearance of wave clouds to the convection produced when the sun warms the ground. He also suggests that in the dark hours the drainage of cold air down the cooling hill slopes interferes with wave formation. By early morning valleys may be filled with almost stagnant "pools" of cold air, but then the rising sun warms some slopes, and before the convection and wake production becomes general there may be a brief renewal of wave formation to great heights, while the wind profile near the ground passes through an ideal condition.

These are tentative views which must be developed and tested by careful observation of low-level winds during the periods when high wave clouds form and decay. It will be difficult to make observations in the required detail just at the important places, but improvement of the general theory of wave formation demands this better understanding of the flow near the ground. The theoretical meteorologist is delighted at the necessity of taking to the hills and watching such splendid phenomena as the wave clouds. Their impressiveness can be judged from the following account of a pair of great hill-wave clouds which formed over the Midlands one summer evening.

Among other typical features, these clouds illustrate the extraordinary height to which the effect of even a small hill can extend. It is no uncommon thing for the air at 30,000 feet to rise and fall two or three thousand feet in passing over the Cotswolds, themselves barely 1000 feet high. Near Stockholm I have seen wave clouds at about 20,000 feet remain stationary for two or three hours, over a region in which the tallest hills are 500 feet high. On rare occasions over the Norwegian mountains the brilliantly coloured "mother-of-pearl" wave clouds form at the fantastic height of about 100,000 feet, shining long after sunset with a splendour which has moved scientists there to exclaim in their writings, "It was like a fairy tale!"

THE GREAT HILL-WAVE CLOUDS OF JULY 19, 1952

This was a fair summer day over the southern half of Great Britain. It was cloudy in the north, where the polar front lay stationary across Scotland, forming the northern boundary of a mild tropical air-stream flowing eastwards across England from the Atlantic.

Over the Midlands during the afternoon there were some small clouds formed by convection from the sun-warmed ground in the lowest 5000 feet of air. The only other clouds were some streaks of high cirrus which could be seen far to the north from Dunstable, where the following observations were made. In the evening the convection diminished, the low clouds began to disappear, and the sky became almost cloudless. Just an hour before sunset thin, evanescent patches of cloud formed some distance away to the west, in the part of the sky near the sun. Very soon they became thicker and persistent, to form a large high cloud stretching several miles across the wind direction and growing steadily by extending down-wind. Within twenty minutes it had grown to a substantial size, as shown in Fig. 5 (*lower right*), and a similar cloud had developed a little farther away and to the north, directly in the glare of the sun. The two clouds were estimated to be forming over the Cotswolds near Evesham, and over the Clent and the Lickey hills just south of Birmingham (Fig. 6). The height of these hills varies between about 700 and 1000 feet, but the clouds formed at about 25,000 feet, where the temperature was −20°C.

Both clouds continued to extend down-wind (Figs. 7, 8). Near the formation region they had a dappled or compact structure typical of clouds composed of droplets, but farther down-wind there was a progressive transformation into a fibrous appearance more like that of cirrus clouds, showing that the cloud particles were becoming predominantly ice crystals. The southern half of the sky remained quite cloudless, and, perhaps surprisingly, no wave clouds formed over the mountains of Wales. At sunset the nearer hill-wave cloud became lit from beneath and silky strands of ice crystals falling from it could be seen very clearly against a higher dappled structure (Fig. 9). Soon afterwards the clouds glowed a wonderful angry red, but then, some twenty minutes after sunset, quite suddenly the clouds in the west began to break. The great hill-wave clouds were no longer renewed over the hills, while their residues continued to move eastwards and were soon lost in darkness and behind freshly-forming banks of low cloud at about 5000 feet. In Fig. 10 a few faint crystal-wisps are all that remain of the great hill-wave clouds of the previous figure, taken nearly an hour earlier.

From the routine meteorological observations made that afternoon it seems that the air in which these wave clouds formed must have been lifted rather more than 2000 feet (twice the height of the hills). Evidently only for an hour and a half did the hill-waves have this size at the cloud levels (more than twenty times higher than the hills). To discover how even small hills can so strongly disturb the air at great heights, meteorologists must be prepared to have their probing balloons and aircraft ready for use on the spot and at a moment's notice. An hour's delay may mean the opportunity lost, and a wait of several weeks before another one arrives.

REFERENCE

A recent article by G. C. Corby, in the *Quarterly Journal of the Royal Meteorological Society* for October 1954, presents a comprehensive review of knowledge of air-flow over mountains.

POWER FOR THE ARID ZONES

THE HARNESSING OF WIND POWER AND SOLAR ENERGY

E. W. GOLDING, M.Sc.Tech., M.I.E.E.

The discovery of means whereby the under-developed areas of the world may economically be made to take a greater share in providing for the needs of the rapidly growing population, presents a fascinating, yet important and urgent, problem. Such areas have widely varying characteristics and have remained undeveloped for different reasons, geographical, political and climatic. Obviously, areas possessing valuable natural resources in the form of minerals, or abundant hydro power, good agricultural land and equable climate are developed first, leaving the less promising areas to be dealt with by succeeding generations as the need, or the possibility, arises. Even now the vast Arctic and Antarctic regions remain outside the bounds of practicability in development of this kind, but some of the neglected tropical areas and parts of the arid and semi-arid zones (which have a total area approaching *one-third* of the earth's land surface) could be made to produce food and other valuable raw materials.

The governments of countries which include these dry areas in North Africa, the Middle East, India and Pakistan, Australia and some western parts of the United States and of South America, are much interested in the possibilities of developing such land. Research to this end has been stimulated by international collaboration organised during the past few years by Unesco through its Arid Zone Research Advisory Committee.

Water is, of course, the first need in the arid zones, and their development requires the solution of the problem of providing water in sufficient quantity. A cover of vegetation is another essential, and therefore intensive scientific studies of plant and animal life in the deserts or semi-deserts, particularly the studies of ecologists, can give a valuable lead towards the improvement of such land agriculturally. Hence, the wisdom of organising Unesco conferences on arid zone hydrology and ecology in 1952 and 1953.

The provision of energy for development is, however, only a little less important than water; energy is needed to pump water as well as to supply the domestic and agricultural power requirements of the people who are to bring about this development. In an industrialised and thickly populated country such as Britain, most of the inhabited areas are covered by electricity supply networks, but it proves expensive to take electric power to the more remote districts where the population is thinly distributed. For many of the areas classified as arid zones, a mains electricity supply is virtually out of the question—at least in the early stages of development. Power would have to be transmitted at high voltage, over hundreds of miles of difficult country, only to be met with serious distribution problems due to the sparcity of the population in the area concerned. Reliance on local, oil-driven power stations, or the use of individual oil engines, instead of large power stations, would certainly remove the difficulty of costly electrical transmission but, in its place, one would have the high cost of transporting the oil fuel and items needed for plant maintenance.

The most obvious alternative to the use of imported energy is the employment, for power purposes, of the two energy sources which occur naturally in many of the arid zones, namely the wind and the sun. But these sources demand relatively large and expensive power plant so that, for economy the energy becoming available must be used as fully as possible.

Recently, under the joint sponsorship of Unesco and the National Institute of Sciences of India, an international conference on "Wind Power and Solar Energy" was held in New Delhi, and many aspects of the problems connected with their exploitation were discussed. The venue was particularly appropriate because India, with a population of some 367 millions to feed, has extensive—and *extending*—arid or semi-arid areas, particularly in Rajasthan and the adjoining districts. The Indian Government has already recognised the potentialities of solar radiation and wind power for the development of some parts of the country; the National Physical Laboratory at New Delhi has developed several forms of solar cookers and water heaters, while a wind power committee, set up under the Council of Scientific and Industrial Research, has put in hand wind power studies. The presence at the conference of engineers and scientists from the United States, South Africa, Russia and Australia, and from Britain, France, Denmark, Holland, Germany and other parts of Europe, as well as from India, Pakistan, Israel, Nepal, Burma Ceylon and other eastern countries, ensured that the problems of the latter group were presented to the interested experts from the more industrialised countries.

Prof. D. Dresden (Netherlands) introduced the sessions on wind power. He outlined the progress which had been made during recent years in Britain, France, Denmark and Germany and described the activities of the wind power group of O.E.E.C. of which he is chairman. He suggested that wind-driven centrifugal pumps, which are suitable for water pumping in arid areas, would enable greater advantage to be taken of the energy from high winds than is possible with constant-speed windmills driving electric generators connected to networks. Compressed air, supplied from wind-driven compressors, might also be used to afford some storage of energy, while wind-electric plants of up to 80–100 kilowatt capacity could be made to combine the duties of water pumping and electricity generation.

Two papers by Indian delegates discussed the possibilities of wind power for water pumping and other agricultural purposes, and for the generation of electricity. Mr. R. V. Ramiah, head of the Engineering Division of the Indian Agricultural Research Institute, dealt with the experiments which had been made with the object of improving the present water-pumping methods using bullock power. Two indigenous water lifts are in common use—the Persian wheel (with mechanical efficiency of 32–39%) and the chara, or leather-bucket mhote, for which the efficiency may be about 50%. The output from such machines can be 5000 gallons per hour when the lift is only 20 or 30 feet and a pair of bullocks, which are used in addition for other farm purposes, can provide supplemental irrigation for an area of 10–15 acres. The 5000 gallons per hour figure is on the high side, even with a short lift; when the lift is 50–60 feet, an output of only 1200 to 1500 gallons per hour results. Careful investigation of the wind régimes at possible pumping sites is needed because periods of high wind speeds may not coincide with those when supplementary irrigation is most wanted. A wind pump designed so that it can be complementary to bullock power at a given site is required. It may be that a more economic method of utilising wind power for pumping would be to locate a wind-driven electric generator on a well-exposed site close to the well and to use an electrically-driven submersible pump.

The second paper, by Mr. U. J. Bhatt, chief engineer for the State of Saurashtra (which occupies a coastal area lying between Bombay and Karachi), called attention to the power demands of this rapidly developing area which has an electricity network fed from thermal power stations. Heavy transport charges make fuel expensive and the generating cost sometimes exceeds 2*d*. per kilowatt-hour. Yet there are sites, particularly near the coast, where mean wind speeds of 22 m.p.h. occur in the windiest months of the year, so that wind-generated electricity may well be economical.

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FIG. 2 (*right*)
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raising steam

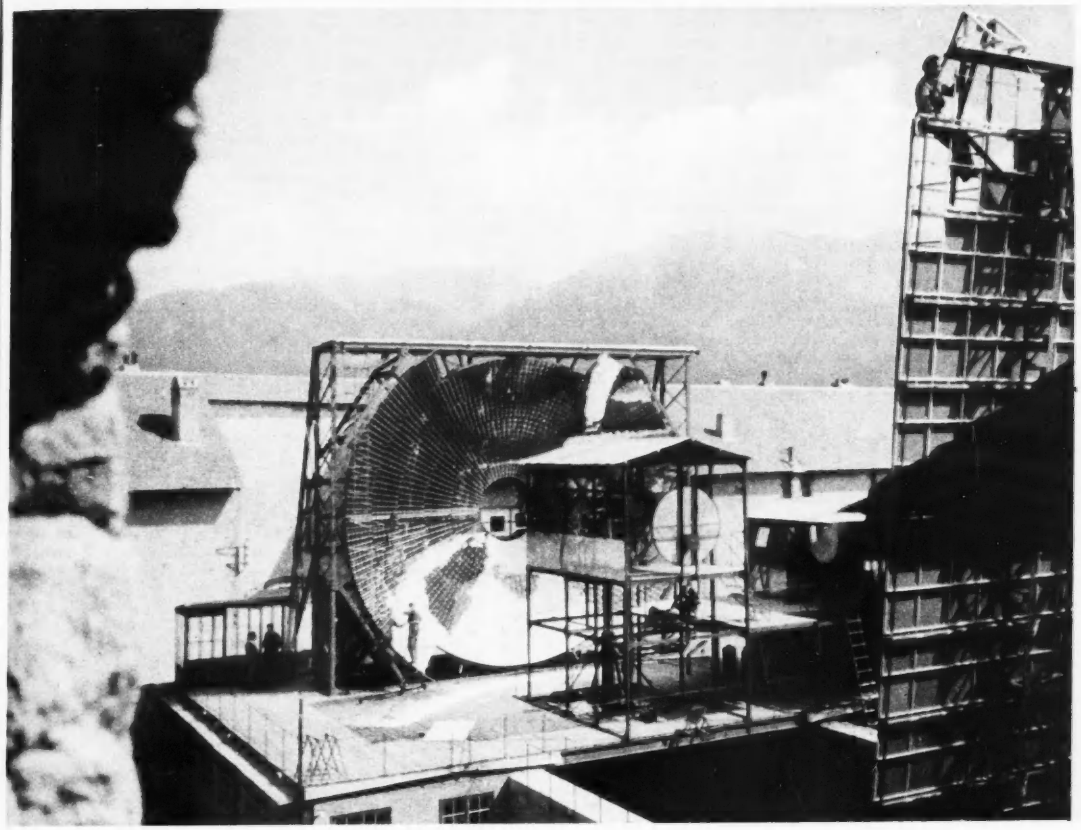

FIG. 1 (*above*). The huge concave mirror, showpiece of the French solar energy laboratory on Mont Louis in the French Pyrenees. This mirror is 12 yards in diameter, and is built up of 3500 glass reflectors. The sun rays focused by it are utilised in the solar furnace installed in front of the mirror.

FIG. 2 (*right*). The articulated solar reflector at the National Physical Laboratory, New Delhi. This concentrates solar energy, which is being used for raising steam.

Dr. P. Nilakantan, the convener of the Indian wind power committee, emphasised the need for wind surveys to provide accurate information as a basis for energy estimations; survey methods similar to those used in Britain are being followed in India. Drs. L. A. Ramdas and K. P. Ramakrishnan, of the Indian Meteorological Office at Poona, gave data on the variations of wind speed in India. A knowledge of the maximum wind speed is important for a windmill designer; gusts of 99 m.p.h. have been measured at Allahabad and Jamshedpur.

Wind-power developments in Denmark, where almost continuous progress has been made since the original establishment of a research station under the late Prof. P. La Cour in 1891, were described by Mr. J. Juul, of the South-East Zealand Electricity Company. Some forty years ago the number of Danish windmills, used for corn-grinding and for general power purposes on farms, was about 33,000 with a power capacity equivalent to some 200,000 kilowatts. Since World War II, Mr. Juul has been responsible for the construction, in succession, of a 13-kilowatt and 45-kilowatt windmill driving A.C. generators. He gave details of his experiments and outlined (with a schedule of estimated costs totalling £50 per kilowatt) the design of a 200-kilowatt machine, the next step in his development programme. Both Mr. Juul and Dr. U. Hütter (Germany) emphasised the need for detailed wind surveys as a basis for energy estimations. The latter, who is the designer of a successful 8–10 kilowatt wind-electric plant, also discussed how to determine the best size and rated wind speed for wind-power plant for farms and to decide the minimum essential storage of electrical energy. Electrical energy supplied via a battery may cost three to four times as much as that used directly, without storage. Although non-electric wind pumps may have the merit of low cost, a centrally situated wind-electric plant on a good site has advantages for general purposes including pumping.

The economy of Israel depends heavily on imported oil for power production. In the centre and north of the country there is an electric grid fed with 230 megawatts from oil-fired steam generating plant, while the agricultural communities have diesel-driven sets of individual capacity up to 200 kilowatts. A wind survey, covering the whole country and following the British methods, was started in 1952 and is directed by Mr. J. Frenkiel, of the Research Council of Israel. He said that sites in the Negev—the desert region forming the southern half of Israel—were chosen first because of the call for water pumping there as an aid to its development by agricultural settlements. Later, measuring installations were made in the centre and north of the country. The windiest sites are on the Napthali mountain ridge in Upper Galilee; some of these have annual mean wind speeds in the range 15 to 20 m.p.h. Encouraging experimental results have been obtained also from small wind power plants, up to 3 kilowatt capacity. One of these, at Eilat on the Red Sea coast, had a maximum monthly net output of 348 kilowatt-hours (from a machine of nominal capacity 3 kilowatts).

The general problem of the economic use of wind energy in arid zones was discussed by Mr. E. W. Golding (Britain) who emphasised that two very important requirements were (i) a knowledge of the detailed wind régime as determined from survey measurements, and (ii) careful planning of the loads and loading schedules to ensure the fullest use of random energy without using batteries for storage. He said that water pumping, thermal-storage heating, and other loads with inherent storage were ideal absorbers of wind power output. He dealt with the design of wind power plant to suit local conditions and showed that a wind power capacity of 50 kilowatts, located at a site with an annual mean wind speed of 13 to 14 m.p.h., could provide over 100,000 kilowatt-hours per annum which may suffice for 100 or more people in an arid zone community. The manufacturers interested in the production of wind-power plants must be helped by being given firm indications of both the design requirements and the magnitude of the probable demand.

The group of papers on solar radiation was introduced by Prof. Farrington Daniels of the University of Wisconsin, who is well known for his researches on photochemistry and photosynthesis. He said the world needed to pay more attention to the use of its energy income in the form of solar radiation instead of continually drawing on its energy capital—the various fossilised fuels. The world consumption of food averages 2500 kilocalories per person per day, whereas the figure for fuel consumption is ten times as great—25,000 kilocalories per person per day—and is rapidly growing. Exhaustion of our fuels will eventually force the large-scale use of the inexhaustible solar radiation. For the world as a whole this may not come about for centuries, but in the arid zones transport costs make it necessary, even now, to use the local resources of solar energy. Solar cookers and water heaters are already technical possibilities; solar engines may be uniquely favourable for water pumping in arid zones even though, at present, they may have to be small, cheap and somewhat inefficient. The solar distillation of saline water is another promising application. One of the brightest hopes for the future in this subject lies in the practical applications of the solar battery recently evolved by the Bell Telephone Laboratory. Prof. Daniels called attention to the possibilities of simple and cheap construction for solar energy collectors through the use of aluminised plastics and to the important progress which had been made in the direct conversion of sunlight into electricity in crystalline semi-conductors.

In assessing the possibilities of using solar radiation for any purpose on a widespread scale it is clearly necessary to possess data on its distribution in different parts of the world. Papers by Mr. J. N. Black (Australia), Prof. A. E. H. Bleksley (South Africa) and Drs. L. A. Ramdas and S. Yegnanarayanan (India) dealt with this subject. Unfortunately, owing to the difficulty of measuring incoming radiation, data are available from only 150 meteorological stations and over three-quarters of these are in North America or Europe. The amount of cloud, of course, affects the radiation, Q, actually received at any time and place and Mr. Black gave the formula as

$$Q = Q_A(0{\cdot}803 - 0{\cdot}340C - 0{\cdot}458C^2),$$

where Q_A is the potential radiation if the atmosphere were perfectly transparent and C is the mean amount of cloud, in tenths.

The Agricultural Meteorology Division at Poona has studied the utilisation of solar radiation by various field crops in India. Sugar-cane, with an annual yield of 40 tons dry matter per acre, does best with a utilisation of 2% of the radiation received by it during its growing season. Sorghum comes next with 1·76%; rice uses 1·17%, and wheat only 0·44%. These low efficiencies are a challenge to science, and research workers have already responded to it by starting investigations of the economic possibilities of growing edible algae which are more efficient in this respect than the standard crop plants on which agriculture is based.

Mr. N. W. Pirie, of Rothamsted, read a paper on "Power from Leaves" which showed that crop yields were greatest in tropical areas, mainly because of the shortness of the period of adequate growing temperatures in the temperate zones. After discussing the possibilities of the alga *Chlorella* Mr. Pirie turned to the question of increasing the yields of other agricultural crops and summarised his argument by quoting P. C. Putnam's figure of $3{\cdot}2 \times 10^{12}$ kilowatt-hours as the annual contribution of farm wastes to the world's energy consumption of some 25×10^{12} kilowatt-hours per annum. He suggested that this contribution should be increased and that farming might be somewhat reorganised with this in mind.

The solar energy developments at the National Physical Laboratory, New Delhi, were described by Drs. K. N. Mathur, M. L. Khanna and A. L. Gardner. These experiments have been concerned with four applications: domestic cooking and water heating; lift irrigation; water distillation; air

FIG. 3. The 8-kilowatt Allgaier wind-driven generator.

FIG. 4. The Enfield-Andreau generator has the same power output as the Allgaier.

FIG. 5. A typical landscape in the Negev, where the Research Council of Israel is interested in developing wind power.

conditioning and refrigeration. The small cooker, with about 9·6 square feet of collecting surface in the form of a concave anodised aluminium mirror, produces some 350 watts in bright midday sunshine, but its already low cost must be further reduced if it is to be used by the Indian peasants. Mr. Gardner's design of articulated collector, consisting of a large number of small plane mirrors, mounted on rotatable bars and focusing at a fixed point above them, aims at reducing costs in cooking, water heating and steam raising. A collector (with 192 square feet of mirror surface) of this form raises steam to drive a small water-pumping engine. Another form of collector for the same purpose is a large paraboloidal mirror, with an output of 1·5–2 kilowatts, which can drive a hot-air engine. At New Delhi there is bright sunshine for over 2700 hours per year and, in a solar water heater having 58·7 square feet of glazed area, the absorption rate was found to be 10,500 British Thermal Units per hour at 1.30 p.m.

Mr. M. Beau paid a graceful and warm tribute to the work of the late Mr. A. Nizery who, until his death last February, was a very active member of the Unesco Arid Zone Committee. Mr. Nizery was justly famous for his researches on the use of the thermal energy of the sea as well as for his work in the research department of Eléctricité de France and at the National Hydraulics Laboratory at Chatou. The French marine thermal power plant at Abidjan, on the Ivory coast of French West Africa, is well known but the importance of its complementary function as a producer of fresh water, as a by-product, is not always appreciated. A marine power plant of sufficient capacity to supply the energy needs of a town can also provide all the necessary fresh water for the same town, e.g. a 10,000-kilowatt plant could also produce 3¼ million gallons of fresh water daily.

The power of a marine thermal plant is approximately proportional to the square of the difference in temperature between the warm surface water and the cold water deep down in the sea. The efficiency of the plant, therefore, may well be increased economically by a preliminary superheating of the surface water through solar radiation, covering the surface of the water by glass plates, or even by films of oil, which reduce evaporation from the surface. The experiments made with this aim in shallow lagoons at the newly established solar energy laboratory at Dakar were described by Dr. H. Masson. Another industrial application of solar radiation which has passed successfully through the development stage is that of melting metals. Very high temperatures (3000 to 3500°C) can be attained and the product has a high degree of purity. Dr. Felix Trombe, who is in charge of the Solar Energy Laboratory at Mont Louis, in the Pyrenees (an illustrated description of this laboratory appeared in DISCOVERY, Sept. 1953, pp. 279–81) gave details of the construction of his high-temperature furnace which depends on a collector, 1450 square feet in area. This is made of 540 plane glass reflectors, silvered on the back and then backed with copper which is finally varnished. No appreciable deterioration has been observed in five years of operation. The furnace charge may be from 30 to 100 kilograms (66 to 220 lb.) in weight.

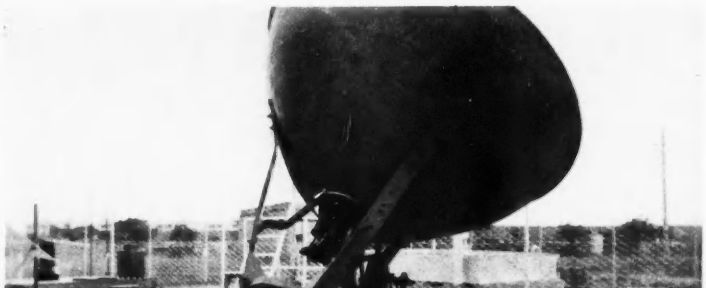

FIG. 6. Paraboloidal solar reflector operating a small water pumping engine at the Indian National Physical Laboratory.

It is perhaps not generally realised that the U.S.S.R. has nearly 1¼ million square miles of arid zones of which about a quarter is sandy desert. These areas have 150 to 200 clear sunny days a year, and it is not surprising that the possibilities of using solar radiation have been investigated by the Heliotechnical Laboratory at the G.M. Krzhizhanovsky Power Institute of Moscow. Its director, Dr. V. A. Baum, described some of the researches, particularly in Tashkent. For temperatures up to 100°C, plane collectors are used for water heating, air heating and the drying of vegetables and fruit. High temperatures demand energy-concentrating reflectors; these are of either paraboloidal or parabolic-cylindrical form, and give concentrations of 300- to 5000-fold and 20- to 70-fold respectively. A paraboloidal concentrator, of 10 metres diameter, built in 1947 at Tashkent is used to raise 50 to 60 kilograms (110 to 132 lb.) of steam/hour at a pressure of 7 atmospheres. Dr. Baum considered 25 metres diameter as the maximum economic size for a plant of this kind. Solar equipment, in the form of a three-stage distiller, for demineralisation of salt water, produces annually 75,000 tons of distilled water and 12,000 tons of ice. A Russian solar cooker with an aluminium paraboloidal reflector 1·2 metres diameter produces about 600 watts in full sunlight. Mr. Z. R. Kothawalla urged the application of wind and solar energy to assist the semi-desert, but important pasturing, areas in N.W. India—the "stud-farm" of India.

Finally, a paper by Mr. E. W. Golding and Prof. M. S. Thacker made some suggestions for the combined use of wind power and solar radiation—assisted by a little power from the burning of waste material—to supply all the energy needs of a community in a developing arid or semi-arid area.

An example was taken for a site with an annual mean wind speed of 10 to 12 m.p.h. and ample sunshine, and assuming the existence of a few tons per annum of waste material. By the installation of 25 kilowatts of wind power plant, for lighting and motive power, some 100 to 150 square metres of solar collectors to provide water heating, distillation, air conditioning and refrigeration, and two steam engines of 3 h.p. capacity, a community of forty to fifty families could be catered for without resorting to any appreciable amount of energy storage. But, careful planning of the installation and the method of loading would certainly be needed to ensure the most effective use of the annual energy which could be made available.

(The proceedings of the New Delhi conference will in due course be published by Unesco, 19 Avenue Kléber, Paris 16eme; any inquiries about them should be addressed direct to the Secretary of the Arid Zone Research Advisory Committee at that address.)

FAR AND NEAR

Atomic News

Two new appointments have been announced by the U.K. Atomic Energy Authority. MR. D. E. H. PEIRSON becomes secretary to the Authority. He is aged 39, and has spent much of his career in the Ministry of Supply. COLONEL G. W. RABY, aged 54, has been appointed deputy director of engineering to the research group of the Authority to take up his duties in April.

* * *

An international conference on the peaceful uses of atomic energy is to be held in Geneva in the summer. According to *The Times*, this proposal was unanimously approved by the United Nations General Assembly. The newspaper described it as "part of President Eisenhower's 'atoms for peace' plan".

Simultaneously the Russians announced their counterpart of the Eisenhower plan, whereby they will give technical aid in the peaceful development of atomic energy to five Communist countries, including the Chinese People's Republic. Hungary was not mentioned in the Russian announcement.

An editorial in *Pravda* has stated that the Soviet Government is willing to present a report concerning the first industrial atomic power station in the U.S.S.R. and its work, to the Geneva conference on atomic energy mentioned above. The Russians claimed that this power station with a capacity of 5000 kilowatts was brought into operation on July 1, 1954, and plans have been announced for other power stations with outputs of up to 100,000 kilowatts.

* * *

The Times reported on January 26 that the president of Atomic Energy of Canada Ltd., Mr. William J. Bennett, has stated that an atomic power station is to be built in Canada. He did not say where it would be, but hinted that it might be somewhere in southern Ontario. Work on blueprints will be started in the spring and the station is expected to be producing its first power early in 1958.

Another important discovery of uranium ore has been made in South Australia. This deposit is located in the north-east of the State, near Crocker's Well—about 35 miles west of Radium Hill.

S. Africa has disclosed figures for the value of its uranium exports for the first time. These exports during the first nine months of 1954 were worth the sum of £9,132,790.

* * *

The U.S. Navy's atomic submarine *Nautilus* had completed two successful trial cruises by the end of January, including "numerous dives". The trials of this vessel (*see* DISCOVERY, March 1954, pp. 110–15) were delayed because some of its piping developed defects and had to be replaced. The same fault has had to be corrected in the second land-based prototype submarine nuclear power plant which is being built at West Milton, New York State.

The Chief of the U.S. Air Staff, General Twining, has said that the American Air Force is planning an inter-continental bomber, driven by nuclear power.

Nuclear Physics in the Universities

A question about financial support for nuclear physics in the universities was asked in the House of Commons on January 25. Mr. Skeffington asked: "What steps have been taken to remove from the Department of Scientific and Industrial Research the present financial responsibilities in relation to nuclear physics research in universities, mentioned in the Report of that Department for 1952–3?" Mr. Bevins (Parliamentary Secretary to the Ministry of Works) said that discussions are in progress with the object of finding an acceptable alternative method of meeting the heavy expenditure on nuclear physics research at universities when the present university quinquennium ends on July 31, 1957. He added that this matter is now the active concern of a specially appointed committee on which university nuclear physicists are well represented.

Night Sky in March

The Moon.—Full moon occurs on March 8d 15h 41m U.T., and new moon on March 24d 03h 42m. The following conjunctions with the moon take place:

March

4d 10h	Jupiter in conjunction with the moon		Jupiter	2° N.
13d 22h	Saturn	,,	Saturn	6° N.
21d 02h	Venus	,,	Venus	4° S.
22d 11h	Mercury	,,	Mercury	7° S.
27d 11h	Mars	,,	Mars	3° S.
31d 16h	Jupiter	,,	Jupiter	2° N.

The Planets.—Mercury rises about 5h 50m up to the middle of the month and at 5h 25m at the end of the month, but in all cases the planet is too close to the sun for favourable observation—in the last case it rises only quarter of an hour before sunrise. Venus rises about 5h up till the middle of March and at 4h 40m on March 31, an hour before sunrise, and will be conspicuous in the eastern sky, its increasing N. declination making it more easily observed in the northern hemisphere. Viewed with binoculars its crescent form early in March will be seen to change from day to day until the visible portion of the illuminated disk, which is 0·651 on March 1, has increased to 0·753 on March 31. During this time its distance from the earth has increased from 87 to 106 millions of miles, and its stellar magnitude has changed from −3·7 to −3·5, a slight decrease in brightness occurring. Mars rises at 22h 30m throughout the month. Its eastward motion in Aries is obvious, though it is not close to any conspicuous star until about March 26 when it nears δ Arietis. Its distance from the earth varies from 176 to 197 millions of miles and its stellar magnitude from 1·4 to 1·7. Jupiter—visible throughout the night sets at 5h, 4h and 3h, on March 1, 15 and 31, respectively; its stellar magnitude varies from −2 to −1·8 and its distance from the earth from 424 to 464 millions of miles. Its westward motion—almost impossible to detect with the naked eye—brings it a little closer to δ Geminorum until March 16 when it is stationary, after which it has an eastward motion. Saturn rises at 0h 10m, 23h 10m and 22h 05m, on March 1, 15 and 31, respectively. Its westward motion takes it nearly midway between α and γ Librae towards the end of the month and its stellar magnitude varies between 0·6 and 0·5 owing to its distance from the earth decreasing from 886 to 848 millions of miles during March. Spring equinox takes place on March 21d 10h.

Television Novelties

The Television Society's Annual Exhibition, which was held at University College from January 6 to 8, is intended to give an opportunity to manufacturers to show recent experimental products and items of research. With admission restricted to ticket-holders, the exhibition is modelling itself on the lines of the Physical Society's Exhibition, and should therefore provide a useful shop-window for serious technical visitors and yet another welcome gossip centre.

One or two outstanding items among those shown by the thirty-odd exhibitors were: a new light-weight projection television receiver (J. S. Fielden Ltd.) with focus control to give any size of picture from 24 inches by 18 inches upwards. This costs only 98 gns. A four-gun cathode-ray tube (20th Century Electronics) with a screen divided into four quadrants of different phosphor colour. This could be used as a waveform monitor for colour television, giving the waveform in the appropriate colour, or as a miniature picture monitor for each of the colour channels. Fortiphone Ltd. showed examples of transistor H.T. generators suitable for Geiger counters or cathode-ray-tube supply. An output of 120 volts 200 μA. can be obtained with an input of 3 volts.

A particularly interesting demonstration of the effects of ion burn and the so-called "cross burn" was given by the Edison Swan Co. It is possible to prevent negative ions from reaching the

c.r.-tube screen by means of an ion trap, but unless the screen operates at the same potential as the anode it is still possible to have screen ion burn. This is due to positive ions focussed by the electron lens formed by the inner coating and the screen, and takes the form of a circular spot in round bulb tubes and a cross in rectangular bulbs, where the electron lens is not symmetrical. The effect is prevented by aluminising the screen.

It is intended to hold the Exhibition in the early weeks of January in each year, and the date of the 1956 exhibition will be advertised in the technical press in due course.

Industrial T.V. for British Electricity Authority

Behind the announcement that Marconi's Wireless Telegraph Co. Ltd. are to supply eight industrial television equipments to the British Electricity Authority, lies an interesting story illustrative of the extreme versatility of this new industrial tool.

For many years past, two major problems have confronted boiler-room engineers; one was the virtual impossibility of knowing exactly what was going on inside the furnace itself; the other, how best to effect a constant supervision of the boiler water-level. Many devices have been tested to overcome these difficulties. An industrial television equipment should prove a great asset to the combustion engineer, and eight such units are accordingly to be installed at the B.E.A.'s new power station at Willington, in Derbyshire.

A similar T.V. unit is being used at Sellafield in order to see what is happening inside an atomic pile.

Liverpool's Synchrocyclotron and other Metro-Vick Instruments

The January 1955 issue of the *M-V Gazette* contains information about a number of items of scientific equipment constructed by Metropolitan-Vickers Electrical Co. Ltd. These include the 156-inch, 400-MeV synchrocyclotron made for Liverpool University—the largest of its kind in Europe. This is now in operation producing an external beam of protons. The beam current is about a thirtieth of a microampere, about a hundred times that available from similar cyclotrons in the United States. This machine will be used for experimental work on the properties of fast nuclear particles, particularly mesons.

The company was also responsible for the 300-MeV synchrotron at Glasgow University, now operating satisfactorily at above its nominal energy rating, in fact at 330 MeV. In this machine, an electron beam strikes a target giving off x-rays, which are used for production of mesons.

A prototype electron microscope which has greater versatility than the EM3 model has been made. The performance of this model, known as the "EM3A", has been very promising, and the prototype aroused great interest at the International Conference on Electron Microscopy held last summer. It has been decided to standardise on this model for early manufacture.

This report mentions the new x-ray machines for therapeutic use which were described in the recent DISCOVERY article by C. L. Boltz (January 1955, pp. 34–6), and it says that as a result of investigations in the company's Research Department it seems likely that the linear accelerator will have many non-medical applications as an x-ray generator, e.g. for the radiography of metals and sterilisation of foodstuffs.

In the field of diagnostic x-ray equipment, the company has developed a 100-A., 90-kV mobile x-ray unit which was designed to provide high-powered radiographic facilities at the patient's bedside or away from the main x-ray rooms. Several have been ordered for use in Ministry of Health hospitals. Another medical item is the improved form of portable direct-writing electrocardiograph developed in conjunction with Edison Swan. This instrument gives an immediate record on paper without the need for any photographic processing, weighs only 40 lb. and is designed for mains operation.

£6000 for D.D.T.

The Royal Commission on Awards for inventions used during the war has recommended a joint award of £6000 to the Swiss company of J. R. Geigy S.A. of Basle, Switzerland, and the Geigy Company, of Manchester, for the preparation of D.D.T. The insecticidal properties of D.D.T. were discovered in the Geigy laboratories, and Swiss patents on this substance were taken out in 1939. 1942 saw the introduction of this powerful new insecticide in both Britain and the U.S.A., and both countries made great use of it during the war. According to T. F. West and G. A. Campbell, authors of *D.D.T.: The Synthetic Insecticide*, the Swiss firm succeeded in sending not only the results of their D.D.T. researches to England, but also a large quantity of Gesarol, an insecticidal preparation containing 5% D.D.T. This was done via the British Legation at Berne and the British Consul at Basle.

Tracking Locust Swarms by Radar

In 1946 J. W. Ryde first suggested the possibility of detecting flying locusts by radar, and this has now been successfully followed up by locust survey workers. In a letter to *Nature* (Jan. 8, 1955, p. 77), R. C. RAINEY of the Desert Locust Survey Headquarters, Nairobi, states that the first recorded radar sighting of a locust swarm dates back to March 22, 1954, in the Persian Gulf about midway between Bushire and Kuwait, by H.M.S. *Wild Goose*. This was effected by a naval centimetric combined air- and surface-warning radar set, with a tilted parabolic cheese aerial. The locusts appeared to constitute a swarm of at least 15 miles radius, and were detected at ranges up to 60 miles, over a sector of up to 80°, giving large "fluffy" echoes on a plan-position-indicator, similar to the effects of mechanical jamming. Flying locusts were seen at the time in the light of a 10-inch signalling projector, and dead ones were seen next morning floating on the sea, at a density estimated at about a thousand locusts over 40,000 sq. yd. The locusts proved to be mature (yellow) desert locusts.

The time of the radar sighting was 1700 hours G.M.T. (2015 local time) two hours after sunset and three-quarters of an hour before moonrise; and the report is of considerable interest as evidence of flight in swarm formation in darkness and over the sea, when visual reactions might be expected to have been minimal, and auditory reactions may well have been involved in maintaining swarm cohesion.

"Scientific Intelligence": A Correction

The third paragraph of Chapman Pincher's article "Scientific Intelligence" in last month's issue suffered a change during the making up of the page. It should have read: "Having said that much, it is immediately clear that there is no sharp boundary between Scientific Intelligence and Military, Air or Naval Intelligence as ordinarily understood."

Cereal Photographs: An Acknowledgment

The photographs of new varieties of cereals which illustrated Prof. Harland's article "Breeding Plants for Human Needs" in the January 1955 issue were provided by the Plant Breeding Institute, School of Agriculture, Downing Street, Cambridge. The institute holds the copyright of these pictures, which we reproduced by courtesy of the Director, Dr. G. D. H. Bell.

Mullard's Electronics Display Centre

The Mullard Company has opened an impressive new Electronics Display Centre at their offices in Gerrard Place, London, W.1. One striking feature is the set of twenty-seven panels which most effectively display the full range of Mullard products according to the themes, "What they are" and "How they work", "How they are made" and "How they are used". There is also a cinema in which the visitor may see some of the firm's films and film strips which are produced by Mullard.

Visits to this centre will be encouraged by the company, and these will extend to parties from education establishments, students, the radio

industry, etc. Inquiries about visits should be addressed to: Mullard Ltd., 1 Gerrard Place, London, W.1: *phone* GERrard 9941.

Questions on Emulsion Paints

The monthly Digest prepared by the Building Research Station (Garston, Watford, Herts.) has now produced two sets of notes which answer some of the questions which people are asking about emulsion paints. The first set appeared in Digest No. 50, and the other went into Digest No. 72, which are published by H.M. Stationery Office, price 3*d*. The latter leaflet makes this comment on the durability of these paints: "It can now be said that, outdoors and on suitable surfaces such as brickwork or rendering, the life of properly used emulsion paints is intermediate between that of oil-bound distempers and that of gloss paints; indoors, there appears to be no reason why the durability of emulsion paints when properly used should differ from that of normal oil paints."

Catalogue of Industrial Bacteria

A catalogue of the National Collection of Industrial Bacteria has been published by H.M. Stationery Office for the D.S.I.R. The Department is responsible for the maintenance of a collection of bacteria of industrial interest at the Chemical Research Laboratory, Teddington. This was started in 1950 with a nucleus of about 200 bacterial cultures taken over from the National Collection of Type Cultures, Colindale. Today there are more than 750 different strains in the collection, whose primary function is to supply the needs of industry, research and educational establishments for cultures. These are usually sent out as freeze-dried desiccates in sealed, evacuated ampoules. The catalogue is published under the title *The National Collection of Industrial Bacteria, Catalogue of Strains* and costs 1*s*. 6*d*.

An Electrical Firm's "University"

A new method of training boys leaving public and grammar schools to become professional engineers capable of filling responsible engineering, administrative and sales posts in industry has recently been introduced by the General Electric Co. Ltd. It is an industry-based "sandwich scheme" operated by the company in conjunction with a technological college of standing, the Birmingham College of Technology. In future all boys in this category who are selected by G.E.C. for training will on leaving school at the age of eighteen be given a five-year course, in which full-time sessions of six months at the College of Technology will alternate with six-month periods of industrial training in the firm's works. At the end of the course a young man will have gained exemption from the professional requirements of a body such as the Institution of Electrical Engineers, and will have as good prospects in the company as the man who has spent three years at the university followed by two years as a graduate apprentice.

At the moment about sixty boys at the Birmingham College of Technology are G.E.C. student trainees on the first year of their course. In three years' time this number will have risen to between 250 and 300.

The scope of this scheme, as well as others organised by the company, is described in a book entitled *Professional Training in the G.E.C.* Readers who are interested should write, mentioning DISCOVERY, to: The Controller of Education and Personnel Services, G.E.C. Ltd., Magnet House, Kingsway, London, W.C.2.

Mond Nickel Fellowships

Applications are invited for Mond Nickel Fellowships. These Fellowships, of an approximate value of £900 to £1200, will be awarded to selected candidates of British nationality with

Incidental information
No. 8

items of interest from our laboratory notebooks

"Stilbazo" represents another flight of the chemist's fancy in the realms of abbreviated nomenclature. It stands for *di*-Ammonium stilbene-4 : 4′-*bis*- (1-azo-3 : 4-dihydroxybenzene)-2 : 2′-disulphonate. It can be identified also with equal brevity as H & W Code 9275.7 and is yet another reagent for aluminium.

Catechol Violet, also known as Pyrocatechin Violet, adds to the versatility of Sequestric Acid (ethylenediamine tetra-acetic acid). It is used as an indicator when titrating bismuth and thorium with that protean reagent. (V. Suk, M. Malat and O. Ryba, **Chem. Listy 48,** 203, 533, (1954). **C. A. 48,** 6309, 8114 (1954)). We were immediately in a position to meet such a demand—indicators have always been a speciality of Hopkin & Williams Ltd.

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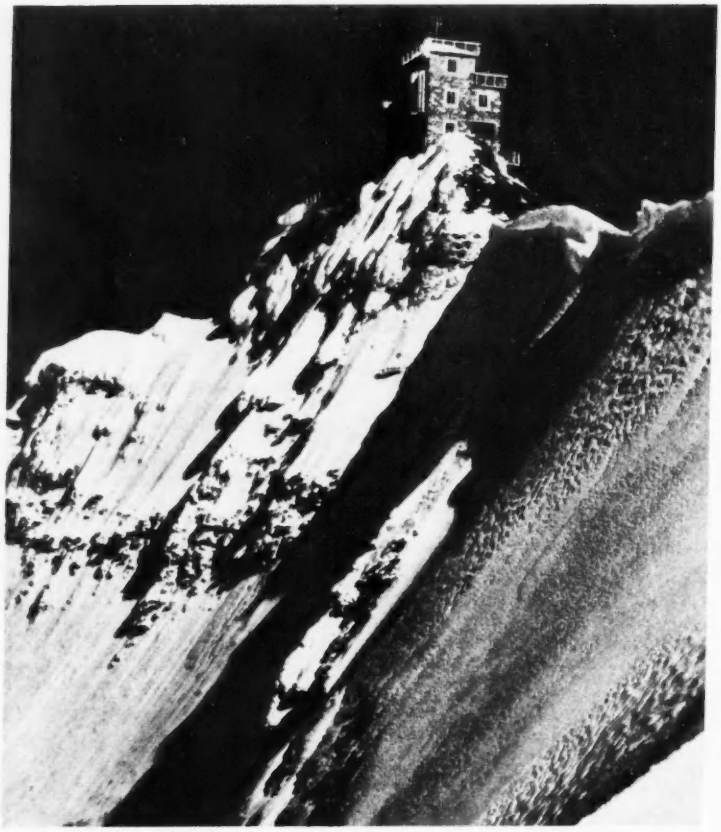

Europe's most famous high-altitude observatory is the Jungfraujoch station 3456 metres up the Jungfrau. There is a network of tunnels beneath it, and a tube railway five miles long connects the observatory with Eismeer.

degree or equivalent qualifications to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British Metallurgical Industries. Each Fellowship will cover one full working year. Applicants will be required to state details of the programme they wish to carry out. Particulars and forms of application are available from: The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

High-Altitude Research Stations

There are at least forty-two high-altitude research laboratories and observatories in the world, according to the report published by the Research Division of New York University's College of Engineering for the Joint Commission on High-Altitude Research Stations, an agency of the International Union of Biological Sciences and the International Council of Scientific Unions.

This 100-page document, the first comprehensive survey of the world's high-altitude research stations, was edited by Dr. Serge A. Korff. "High altitude" is defined in the report as about 7500 feet or above.

Cosmic rays, radio astronomy, meteorology, astrophysics, botany, terrestrial magnetism and solar radiation are a few of the fields which benefit greatly from research at high altitudes.

Some observatories are designed for intensive study in special subjects. The 12,000-foot Mount Fuji Weather Station in Japan is devoted to experiments on the formation of rime ice, which develops from droplets of super-cooled water and from wet snow mixed with glaze ice and frequently forms on aeroplane wings.

The highest station covered by the report is the 18,000-foot Chacaltaya Cosmic Ray Laboratory in Bolivia. The northernmost high-altitude station is the New York University-University of Alaska Mt. Wrangell Observatory, which was established in 1953 on a 14,006-foot Alaskan peak. Southernmost observatory is Argentina's cosmic-ray station in the Argentine sector of the Antarctic.

The United States with seven such research stations has more than any other nation.

Many of the stations have no permanent staff, but the 7000-foot observatory at Kodaikanal, South India, has a staff of thirty-seven.

The Piltdown Hoax

More details about the scientific work that was involved in the exposure of the Piltdown skull hoax have now been published in the *Bulletin of the British Museum (Natural History), Geology*, Vol. 2, No. 6, price £1. There is an introduction written by the museum's director, SIR GAVIN DE BEER, and the authors of the research papers that follow include DR. J. S. WEINER, PROF. W. E. LE GROS CLARK and DR. K. P. OAKLEY. Dr. Weiner's book *The Piltdown Forgery* is reviewed elsewhere in this issue.

Agricultural Scholarships

The Ministry of Agriculture is offering a limited number of scholarships for courses at universities, agricultural colleges, etc., to the sons and daughters of agricultural workmen, smallholders and other rural workers, and to persons who have been paid workers on the land for at least three years. Candidates must have attained the age of seventeen by September 30. Further information can be obtained from the Secretary, Ministry of Agriculture (Room 313), 1 Cambridge Terrace, Regent's Park, London, N.W.1, or from education offices of county councils.

Research Controller of Distillers Company

DR. H. M. STANLEY has been appointed Controller of Research and Development of the Distillers Company in succession to DR. F. ROFFEY, who remains Technical Director of the Company and has taken on the additional duties of Personnel Director of the Company's Industrial Group.

Lewis's Latest Catalogue

H. K. Lewis & Co. Ltd. (136 Gower Street, London, W.C.1) have brought their catalogue of books on General Science and Philosophy up to date with a 1955 Supplement which is obtainable on application.

A Football Pool that Finances Research

The only football pool in Norway is controlled by the Government and the profits are used for the benefit of science and sport. In a letter to *The Times* (3/2/55), the Press Counsellor to the Royal Norwegian Embassy in London

explained how the money is shared out. He stated that 50% of the gross takings are devoted to winnings and the annual profits are divided between sport and science. The first £50.000 profit goes entirely to sports funds, but beyond that it is divided between sport and science, the proportion received by science rising as the total profits increase. For instance, in 1952 sport received £300.000 and science £700.000.

"Century of Aluminium" Exhibition

From June 1 to 11, at the Royal Festival Hall, in London, the aluminium industry will present an exhibition to mark the centenary of aluminium as a commercial metal and to show the wide range of its modern applications.

A Pocket Battery Monitor

The widening field of applications of radioactive substances and equipment has created a demand for simple, easily handled instruments for the detection and measurement of ionising radiation. Among these instruments is the Philips Pocket Battery Monitor, which is used for the location of radioactive ores and for the monitoring of radiation in laboratories. This combines very light weight (1 lb. 9¼ oz. including batteries), small dimensions and sensitivity.

15th International Congress of Zoology

The 15th International Congress of Zoology will be held in London in July 1958 at the Imperial College of Science and Technology, South Kensington.

The president is Sir Gavin de Beer, F.R.S., Director of the British Museum (Natural History); the secretary-general (to whom all communications should be sent) is Assistant Professor H. R. Hewer (Imperial College, London, S.W.7). A Colloquium on Zoological Nomenclature will be held immediately before the Congress, and this will examine in detail the draft text of the *Règles* as amended by the Paris and Copenhagen Congresses, prior to their submission to the Congress for adoption.

I.C.I. Research Laboratories Renamed

Imperial Chemical Industries are renaming their Butterwick Research Laboratories, located at The Frythe, Welwyn, Herts, in memory of the late Sir Wallace Akers, C.B.E., F.R.S. These laboratories, which will now be known as the "Akers Research Laboratories", were formed shortly after the end of the war to undertake fundamental and long-distance research work in various branches of science, and Sir Wallace, in his capacity of I.C.I. Research Director, took a keen personal interest in the project.

Sperry Synchros

The Sperry Gyroscope Company Ltd. describes its range of instrument synchros in a manual which includes data sheets relating to the various models of synchros available, and also explains how these units can be applied. Interested readers should apply for a copy to the firm, whose address is: Great West Road, Brentford, Middlesex.

THE BOOKSHELF

The Piltdown Forgery

By J. S. Weiner (*London, Oxford University Press, 1955, 214 pp., 12s. 6d.*)

The elaborate hoax of the Piltdown Skull and its associated fossils is in the nature of a scientific *cause célèbre*. That the whole thing was indeed a fraud is irrefutable; its exposure has been exhaustively dealt with in two bulletins of the British Museum (Natural History) issued in 1953 and 1955 respectively.

These bulletins, concerned as they are with scientific investigations, make no attempt to determine the identity of the perpetrator or perpetrators of the hoax. Dr. Weiner has endeavoured to do so in this book, and also has set out to describe the historical background, as it were, of the whole episode.

In the first ten of the fourteen chapters of the book he has succeeded in the second objective most admirably. These pages are outstandingly readable, and not only give the background, but summarise parts of No. 2 of the Natural History Museum bulletins; indeed, Dr. Weiner remarks that chapters 5 and 6 are based on extensive paraphrases of parts of that work.

The last four chapters deal with his efforts to trace the hoaxer. They are not convincing, and produce a cumulative impression on the reader that the author, while imagining himself to be an impartial investigator, in effect assumes the rôle of prosecuting counsel.

The impression becomes strengthened when the several chapters are examined in detail. They then seem to be compounded in part of circumstantial evidence, and in part of assumptions, and personal opinions of the author. But the reading public will by no means allow the validity of all the evidence. For example, chapter 12 deals with certain statements that were written *in secret* by one of Dawson's contemporaries, a certain Harry Morris, of whom the author remarks . . . "A strong element of resentment and perhaps jealousy entered into Morris's attitude", and again "Morris became a man with a grievance".

One of Morris's remarks runs "Judging from an overheard conversation, there is every reason to suppose the 'canine tooth' *found at P.Down was imported from France*" (Morris's emphasis).

What is the value as evidence of a report of an overheard conversation written in secret by a man with a grievance! The author himself further depreciates the value of Morris's comments by concluding that the reason these things were not made public at the time was that Morris had strong views on certain "eolithic" flints, to which the existence of *Eoanthropus* was an essential support, and therefore he lay low—not a good recommendation of Morris's character.

It is apparent that these secret comments *may* have importance; but equally they may have been the equivalent of sticking pins into the effigy of a detested person. In view of the circumstances in which they were written, their appropriate place would seem to be a confidential file.

Instances of unwarranted assumptions appear on pp. 149 and 185. On p. 149 it is said that "Mr. Edmunds . . . may have passed this information on . . .", and on p. 185 "Mr. Edmunds, in 1926, saw probably what Dawson had seen . . .". All Mr. Edmunds can say is that he has no recollection of having done (1), and that it is most unlikely that he did so, and that (2) is equally unlikely.

A statement by Dr. Weiner relating to Dawson and the Sussex Archaeological Society has been shown in the public Press to be mistaken.

None of these points may be important individually, yet they are illustrative of the author's method of approach to his subject. The general reader cannot but conclude that the case against Dawson, as presented by Dr. Weiner, far from leading to the finding that "What emerges, however, is that it is not possible to maintain that Dawson could not have been the actual perpetrator", leads rather to the Scottish verdict of "not proven".

The hoax occurred, its scientific aspects have been fully examined, and (let us hope) data have been given us to guard against similar events in the future. It could have been perpetrated only by one of a very small group of people, or by two or more conspiring

together. But one wonders whether it is really necessary to discover who did it, and whether it would not be more profitable for that part of the scientific world involved to laugh at itself for having been duped, and so to close the subject. It is not the first time scientists have been hoaxed.

The book is well printed, but a somewhat long list of errata bears witness to hurried production, and the chapter headings lack dignity.

F. H. EDMUNDS

The Evolution of an Insect Society

By Derek Wragge Morley (*London, Allen and Unwin, 1954, 215 pp., 18s.*)

This book is concerned with the study of a community of Wood Ants' nests in Surrey and also with the antecedents of the wood ants in prehistory. Since the book is intended for the general reader the author is concerned mainly with the social changes which have occurred in the evolution of the wood ants, so that one is taken through a description of the probable history of ant colony organisation with its attendant tale of stronger ties to bind the workers to the nest and the brood within. The author describes how the interchange of food between individuals—present it now seems in some of the primitive Ponerine species—leads to the linkage of individuals by the necessity, or the desire, to exchange or receive food. Since such exhange involves primarily liquid food, a change of diet has to accompany these social changes. Where the primitive Ponerines searched for liquid food only when no brood was in the nest, bringing in solid food when the carnivorous larvae are there, there is a constant supply of liquid food brought to the wood ants' nests. From a study of the history of social life he proceeds to the more immediate history of the particular community.

The daily life of the ant nest is described in a style which can only be called "on-the-spot reportage". Though it is probable that one certain individual has at some time made the journey from the bottom of the nest out along the foraging trail subject to all the distractions which Mr. Wragge Morley describes, but he surely did not follow this ant in the way the vividness of the description implies. Though he shuns anthropomorphism his ants still "yawn", though admittedly "breathlessly".

The author has been successful in setting out a hypothesis for the integration of the duties of the nest which does not credit ants with the political and economic intelligence to which other authors have had recourse. Simply stated, he proposes that ants are essentially excitable creatures bound by their innate behaviour to do certain things. Their level of excitement can be raised by the proximity of an excited companion, say a successful forager which has returned. Their increased excitement causes them to rush out and forage, or be distracted by a larva and so forth. This rules out co-operation in our sense, except that as the job on hand is the job that is done, according to this theory, inevitably a number of ants will be drawn to do the same thing at the same time; but as Chauvin has pointed out, two foragers finding a piece of food do not necessarily pull in the same direction, though they are "co-operating" to the extent that they are both doing the same thing.

Unfortunately there is precious little evidence for this idea, though a reader of this book might infer that it is cut-and-dried and widely accepted. In fact it is not an explanation at all. What, for example, is the means by which excitement is communicated? And what does "excitement" mean? The author attempts to draw a parallel between the whole nest and its individuals, and a nervous system and its constituent cells; but his description of the movements and pulsations of nerve cells in the peripheral system is a fanciful extension from some work on the brain of vertebrates, one of the many uncritical statements in the book. Other examples are the description of chitin as a "compound of protein and glucose" (p. 14), and the legend to Fig. 19 which relates the speed of ants to the length of their legs, for clearly the average local conditions of temperature do affect the speed, for some of the ants chosen are tropical and some from the temperate zone, the correlation cannot be tested unless all the ants are at the same temperature. The uses to which such a term as "habituate" is put would shock a pedantic ethologist.

The book is well illustrated, with a few glaring exceptions when the ants shown are too small for any detail to be seen, and is extremely readable, but the reader must not be too gullible and must be on his guard to distinguish fact from fancy.

J. D. CARTHY

The Natural History of Mammals

By F. Bourlière (*London, George G. Harrap, 1955, 363 pp., 21s.*)

This is an English translation, revised and brought up to date, of a book first published in Paris in 1951. It is intended neither for the beginner nor the specialist, but rather for the interested amateur and the student of field mammalogy, a branch of zoology, which is fortunately now beginning to receive much more attention than in the past. In comparison with field ornithology it is still a much neglected study. The author assumes that the reader has some basic knowledge of mammalian anatomy, physiology and taxonomy; in the introduction he emphasises that he has not endeavoured to write a manual, still less a treatise on the biology of mammals, but rather a plain introduction to the comparative ethology and ecology of wild mammals. The scope of the book is indicated by the chapter headings: Locomotion; Food and Feeding Habits; Home, Territory and Home Range; Defence and Protection; Sexual Life and Reproduction; Development and Longevity; Migration; Social Life; Mammals and Their Environment; Structure and Dynamics of Natural Populations.

Dr. Bourlière's claim is a modest one, for it is clear that this book is much more than an introduction. It is in fact a comprehensive and well-marshalled review or synthesis of the work of a large number of modern field mammalogists. The result is a work of great value, assembling in a readily accessible form the sum of modern knowledge of the subject. The author stresses the gaps in that knowledge, and suggests to future students the most useful lines of research on such problems. The style is clear and easy throughout.

It should be emphasised that this is a serious work. But the reader will not complain of dullness. Many of the aspects of mammalian life described and illustrated may be unfamiliar to many readers. For instance the account of the strange habits of the sea otter, which places a stone on its chest as an anvil on which to crack open the shell-fish on which it lives, and which moors itself to the kelp in order to avoid drifting while asleep in the water, makes fascinating reading, the more so since its authenticity is documented by reference to original field observations.

Throughout the book the sources of information are quoted, and each chapter has its own special bibliography. In addition a general bibliography forms a usefully arranged key to major works of reference on classification, on the taxonomy of the orders of mammals, and on regional treatment. A good index is also provided. The illustrations are well selected, and in particular the numerous line drawings by Paul Barruel admirably assist the text. There is no doubt that this book will be a standard work of reference on field mammalogy for a long time. It is not only a mine of well-arranged information but also an excellent guide to wider reading.

In a work of this character a reviewer would be unlikely to find nothing to criticise. There are a small number of factual errors which are also in the original French text. Several North American rodents which are active all the year round are described as either aestivating or hibernating (p. 86), and a description of the hibernating lodge of the muskrat (p. 91) is unfortunate, since this species is active throughout the winter. At the end of the work a "Taxonomic List of Species, with Common Names" does not provide a world list as might be expected from its title, but is in fact a list of scientific names of the species referred to in the text of the book. But these are small defects that do not detract seriously from the overall value of the book.

R. W. HAYMAN

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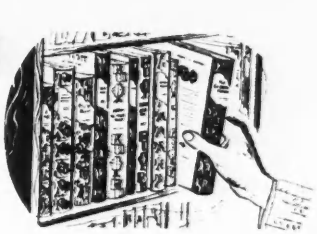

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Guide to the Planets

By Patrick Moore, F.R.A.S. (*London, Eyre & Spottiswoode, 1955, 222 pp., 33 diagrams, 17 photographic and 7 colour plates, 21s.*)

In the period between the two world wars, interest in the solar system was felt to be rather parochial, or at least insular. Astronomy was beginning to "think imperially" and to devote attention mainly to the vast inter-galactic spaces, which offered such new and astonishing conceptions. Today, however, our own family of planets is once more looming large in the popular mind, and the remark of the 19th-century Huxley—"Until human life is longer and the duties of the present press less heavily I do not think that wise men will occupy themselves with Jovian or Martian natural history"—no longer holds good. Within a very few generations now our neighbouring worlds may well become of practical importance to mankind.

Accordingly, after his excellent *Guide to the Moon* published two years ago, Mr. Patrick Moore has produced an equally commendable *Guide to the Planets*. In this he has attempted, he says, "to summarise present information in language that can be understood by anyone"—an aim that is achieved on every page. Though astronomers are maddeningly frustrated in their efforts to ascertain certain facts, such as the rotation-period of Venus and the true significance of surface changes on Mars, it is both cheerful and inspiring to the layman to learn how much solid information has been acquired, not with any sensational projects in view, but in the calm, dispassionate pursuit of knowledge. The thrilling possibilities of inter-planetary travel cannot, indeed, be ignored in any book of this kind; but Mr. Moore is careful to keep all speculation on a sober level, seeing little hope that anyone alive today will witness the first expeditions from Earth to Mars or Venus. Incidentally, he is to be warmly thanked for using the adjective "Cytherean" (after the island near which the mythological goddess rose from the sea) in place of the usual and clumsy word "Venusian".

The best books on popular science contain some history of their subject, thereby rendering it at once both more interesting and more intelligible to the newcomer. Aware of that fact, Mr. Moore gives brief but extremely readable accounts of the discovery of the minor planets, of Uranus, of Neptune, and of Pluto. In addition to this, however, he writes as a practising astronomer, and is able to describe what he has himself observed, either through the splendid 33-inch refractor at Meudon in France, or with his own 12½-inch reflector. The result is a book which should be of the utmost interest and value to the keen amateur, particularly as there are appendices explaining what can be seen with small instruments, and how these may be employed to the best advantage. Altogether, with its admirable photographs, colour plates and diagrams, and with its useful tables of data on the planets and the satellites, *Guide to the Planets* provides a wealth of sound and authentic information most skilfully and attractively presented.

E. N. PARKER

Reproduction and Sex

By G. I. M. Swyer (*Routledge and Kegan Paul Ltd., 1954, 280 pp., 25s.*)

Few subjects have resulted in so much mis-statement and misconception as sex. The publication therefore of a book on this subject by so well-known an authority as Dr. G. I. M. Swyer, who is consultant endocrinologist to the Obstetric Department and director of the Fertility Clinic at University College Hospital, can be warmly welcomed.

In his first chapters Dr. Swyer deals with the physiology of the male and female reproductive systems. He explains the inheritance of sex, the rôle of hormones in sexual physiology, the nature of the female reproductive cycle, the disorders of menstruation and the climacteric. From that point he leads on to a discussion on the anatomy and physiology of conception, pregnancy and childbirth. The problem of infertility is one which is often productive of marital unhappiness, some of it due to recrimination and some as a result of feelings of inferiority, and Dr. Swyer deals with this aspect at some length. He discusses the causes of infertility in male and female and how it can be treated. A short but succinct account of artificial

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Applications to The Works General Manager, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, Springfield Works, Salwick, near Preston, Lancs, quoting 824.

insemination adds to the value of this section. The remainder of the book is largely devoted to contraception, and to a summary of many of the findings in the Kinsey reports. The reviewer was pleased to see attention drawn by Dr. Swyer to a fact that many critics of Kinsey's work ignore completely, and that is the immense amount of care with which the information was obtained and checked, and the completeness of the statistical analysis of the significance of the results. The very nature of the work carried out by Kinsey and his collaborators meant that many aspects of the subject were not susceptible to adequate control, but no investigators could have applied scientific method more assiduously to the study of such a complicated social problem. To have a summary of these complex findings by someone so able in this field as Dr. Swyer is indeed an advantage, particularly as he is able to enlarge and discuss Kinsey's findings in the light of his own experience.

The book concludes with an appendix on the anatomy of the reproductive organs, one on tubal potency (in the female), a glossary and a useful index. It is well written, accurate and interesting. The only doubt which crosses the reviewer's mind is the nature of the readership for whom this book is written. For someone who has done a certain amount of biology it is of course first-rate, and even those with a knowledge of other sciences and who could be expected not to shy violently at scientific terms could read most of it with a certain amount of understanding, pleasure and profit. It is doubtful, however, how that nebulous creature, the intelligent layman, would react to it—to understand it properly he would have to sit down and study it hard, referring frequently to the glossary. The book would, I think, have had a more general appeal if it had had one or two really elementary chapters at the beginning which explained the structures and terms to be used subsequently. However, even those who would find some of the book too hard to follow would understand and profit from many parts of it, particularly the last hundred pages.

This book is one of a series entitled "Survey of Human Biology" and edited by S. A. Barnett.

GEOFFREY H. BOURNE

Man Meets Dog

By Konrad Lorenz (*London, Methuen, 1954, 199 pp., 15s.*)

Dr. Lorenz is an authority on animal behaviour with a most lively and pleasing literary style. The kind of facts which he presents in his books have a ready-made interest for ordinary folk for they relate mostly to animals with which the average person is familiar. His approach, being that of the animal behaviourist, is a novel one, and he sheds much new light on the ways of animals. These facts, coupled with the real flair for writing which he possesses, help to explain why his book *King Solomon's Ring* proved so popular. Everyone who enjoyed that work should hasten to read *Man Meets Dog*. Dog-owners will find it especially interesting, as they will be able to check on Lorenz's ideas, and see how he explains the kind of things which they see their own pets perform. Mention must be made too of his richly comic sense; in his own way, his writings are as amusing as Thurber's stories about pets. But all the time he is presenting accurate scientific facts and hypotheses which stand up to scientific scrutiny; it may well be that these very readable books will encourage many younger people to specialise in animal behaviour, a branch of biological study which is only just beginning to get into its stride and which offers an almost infinite number of stimulating research problems.

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W. IVES
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
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Applications for awards in 1955 must be received before May 1, 1955, by the Director, The Nuffield Foundation, Nuffield Lodge, Regent's Park, London, N.W.1, from whom full particulars and application forms can be obtained.

L. FARRER-BROWN
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